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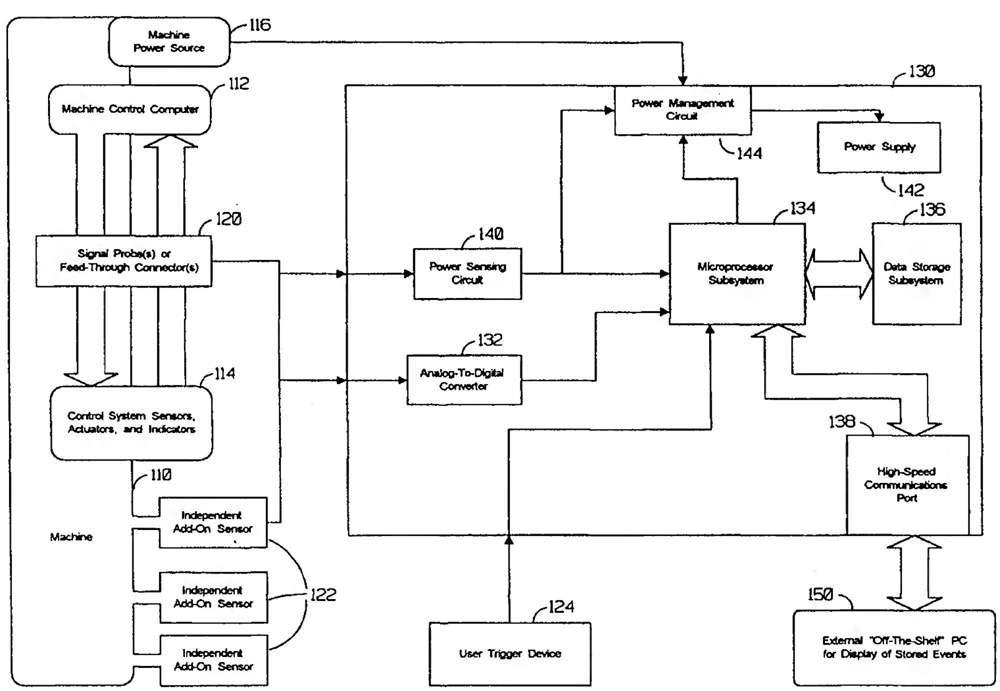
(54) Title: EVENT RECORDER

(57) Abstract



A system is used with a computer–controlled machine having real–time electrical signals corresponding to the operation of a machine, for real–time data processing of electrical signals occurring within the machine. The machine includes a controller (112) and an event node, such as an actuator, sensor, or indicator (122), with an interconnect system disposed between the controller and the event node for exchanging data. The system includes an event data recorder (136) coupled to the interconnect system for selectively storing event data. The machine comprises an automotive vehicle. The event recorder need not be connected to the serial data output of the controller but is directly coupled to the real–time electrical signals occurring between the controller and its associated sensors and actuators. This allows for direct monitoring and diagnostics of the real–time system activity within the automotive vehicle, including intermittent problems which can be missed by or even caused by the controller. The event data recorder can be triggered (124) to store the data by a user input by pressing a push–button positioned on a wire–less transmitter that communicates with the event data (150) recorder. Feedback is provided to the user indicating that the event data recorder is storing the event data.

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EVENT RECORDER

RELATED APPLICATIONS

This application claims the benefit of U.S. Provisional 60/101,230, filed September 21, 1998 and U.S. Provisional 60/145,636, filed July 26, 1999, the entire teachings of which are incorporated herein by reference.

BACKGROUND

In recent years, there has been a rapid increase in the use of microcontrollers and microprocessors (the core elements of most computer-type equipment) to enhance the performance and sophistication of a variety of complex machines, most notably motor vehicles. These "computerized" machine systems invariably consist of a group of sensors, which convert a variety of physical phenomena (such as pressure, temperature, velocity, etc.) into electrical signals ("DATA") that are used to convey information about these phenomena, a group of actuators and indicators, which convert electrical signals ("DATA") into a variety of physical phenomena (such as heat, rotation, switch closure, light, etc.), and one or more controllers, which receive the electrical signals from sensors and - based at least in part on the information obtained from the sensors - produce electrical signals to control actuators and indicators. These electrical signals, or data, can take various forms, from DC voltage levels which correspond directly to the state of a sensor, to data messages controlling and reporting system operation.

The rapid deployment of computerized motor vehicle control systems has been accompanied by a corresponding increase in the occurrence of short-term intermittent failures. Due to the "closed-loop" nature of most computerized machine systems, a momentary anomaly at any point in the system can frequently result in a chain-reaction effect, wherein the original anomaly produces an immediate reaction from another element in the loop, which then produces another immediate reaction

from a third element in the loop, etc. Unless the source of the initial momentary anomaly is being monitored at the exact instant that the problem occurs, and in such a way as to identify it as in fact being the source of the initial anomaly, it is sometimes all but impossible to identify and correct the problem.

The interconnections between the sensors, actuators, indicators, and controllers are accomplished by means of wires and suitable connectors. In order to most effectively access the electrical signals which are present within the computerized machine system, for purposes of monitoring the activity of the electrical signals, diagnosis of the electrical signals, and/or external control of the electrical signals, it is necessary to establish physical connections to one or more of the elements of the machine system. A convenient place to make such connections is at the connectors that exist within the machine system. Various systems have been devised for the purpose of accessing electrical signals within motor vehicles and other electronic systems. Most commonly, these systems have taken the form of wire-piercing probes.

Some prior art systems have utilized a breakout box technique, in which one or more wiring harness connectors with a motor vehicle are disconnected from their mating connectors on a vehicular electronic device and plugged into an external breakout box. The breakout box includes an integral cable assembly that is long enough to allow the breakout box to be located at a distance from the vehicular electronic device and that terminates in connectors appropriate for plugging into the vehicular electronic device from which the vehicular wiring harness connectors were disconnected.

The breakout box is constructed such that each signal in the motor vehicle wiring harness connectors is connected through to the vehicular electronic device and is also connected uniquely to one of several probe terminals, whereby each and any of the signals existing within the vehicular wiring harness connectors can be accessed for connection to external diagnostic equipment. Such systems are hampered by the fact that they are large and cumbersome, and are thus impractical for use in instances where they would remain installed for an extended period of time. Furthermore, modern motor vehicles now have many of their electronic devices located within the engine compartment, increasing the impracticality of

breakout box systems due to the limited availability of space within the engine compartment.

SUMMARY

The problems associated with the identification of the source of an intermittent failure in a motor vehicle produces an extremely inconvenient side-effect, which is the requirement that the motor vehicle be removed from its normal (owner's) use in order that a trained service technician can operate the motor vehicle and observe appropriate test equipment while waiting for the intermittent failure to occur. This results in loss of use by the owner as well as the increased costs accrued as a service technician watches for the problem to occur.

Various systems have been devised for the purpose of monitoring and recording performance data for a motor vehicle, and these systems have enjoyed only a limited degree of success in contributing to the identification and repair of intermittent control system defects. Most commonly, these systems have taken the form of devices which monitor a serial data port on a control computer that is part of the vehicular control system, storing vehicle performance data which is generated by the serial port in a recording device.

Such systems are hampered by the fact that the control computer does not have access to performance data from all devices within the vehicular system (e.g., the pressure level within the fuel system, which is a key performance parameter in modern motor vehicle engine systems) and by the fact that the data presented is the control computer's "interpretation" of the system activity, rather than a reliable indication of the actual system performance. Further, performance data is output from the control computer in serial mode (relatively slow in comparison to system activity) by sequencing through each of the system elements and performance parameters in turn. This results in a time period between data points for a given element in the system that can be sufficiently long so as to allow an intermittent failure to occur between data points, which can result in failure to identify a cause for the failure or, worse, identification of the incorrect element as the cause of the failure.

Other types of vehicular monitoring and recording systems utilize specially installed sensors which are not part of the control system of the vehicle, monitoring and storing data from these sensors in a recording device. Such systems are typically designed for long-term monitoring of vehicular performance, and while providing information that is useful in particular applications, they have difficulty providing the information that is required to identify an intermittently faulty element within the vehicular control system.

Due to the foregoing disadvantages of currently available vehicular monitoring and recording systems, servicing of motor vehicles with intermittent failures has long been a time-consuming, expensive, and frustrating experience for service technicians and vehicle owners. Within the automotive industry specifically, intermittent vehicles, and the failure to repair them quickly and cost-effectively, may represent the single greatest cause of customer dissatisfaction and of dealer re-purchase of problem motor vehicles.

Accordingly, a system and method are provided that monitors and records any of a variety of electrical signals occurring in or around a computer-controlled machine. The monitoring and recording system is particularly useful for recording electrical signals occurring in a motor vehicle, for the purpose of identifying the cause of anomalies, including those of the intermittent type, in the operation of the motor vehicle.

In one embodiment, a system is used with a computer-controlled machine having real-time electrical signals corresponding to the operation of the machine, for real-time data processing of electrical signals occurring within the machine. The machine can include a controller and an event node, such as an actuator, sensor, or indicator, with an interconnect system disposed between the controller and the event node for exchanging data. The system can include an event data recorder coupled to the interconnect system for selectively storing event data. The machine can comprise an automotive vehicle which includes the controller. The event recorder need not be connected to the serial data output of the controller but can be directly coupled to the real-time electrical signals occurring between the controller and its associated sensors and actuators. This allows for direct monitoring and diagnostics

of the real-time system activity within the automotive vehicle, including intermittent problems which can be missed by or even caused by the controller.

According to other aspects, the event data recorder stores event data which is not monitored by the controller. The event data recorder can include an onboard power source to process the event data in the absence of any external power source.

According to other aspects, the event data recorder can be triggered to store the event data by a user input, for example, by actuating an actuator, for example, pressing a push-button. In one embodiment, the actuator is mounted within reach of the operator of the vehicle. For example, the actuator can be mounted on a steering wheel of the vehicle, such as the inside of the steering wheel. The actuator can also be coupled to a wire-less transmitter that communicates with the event data recorder.

The event data recorder can also be triggered to store the event data by an unintentional stall of the engine or a shut-down of a vehicular control system of the vehicle. The event data recorder can further be triggered to store the data by an alarm indication of a vehicular control system. In one embodiment, the alarm indication is a warning lamp.

According to further aspects, the event data recorder includes at least one circuit board shock-mounted to a housing of the event data recorder. The circuit board can include a first cushion member thereon to provide a cushion between the circuit board and the housing. A second cushion member can be further positioned between the first cushion member and the housing. A bolt or screw passes through the first cushion member and the second cushion member for securing the circuit board to the housing.

According to further aspects, a feedback system, such as the flashing of a warning indicator lamp of the automotive vehicle, is provided to alert the user that the event data recorder is installed and working properly. The feedback system can also alert the user to various operating states of the event recorder by flashing the warning indicator lamp at different frequencies or for distinct durations.

According to yet further aspects, a cabling device is provided that connects the event data recorder to at least one electrical system of the machine without damaging any existing electrical wiring. The cabling device can include a plurality of contact pins connected to a plurality of wires for inserting into electrical

connection points of the machine. The cabling device can include a multi-pin in-line connector to provide an interface to an electronic sensor, such as a fuel pressure sensor, which is temporarily attached to the vehicle.

Alternatively, the cabling device is custom made or particularly adapted for the machine which can include at least one connector plug that connects to a computer of the machine, at least one cable jack that connects to sensors and/or actuators within the machine, a plurality of feedthrough wires that connect the connector plug and cable jack, and at least one instrument connector that connects at least one of the feedthrough wires to the event data recorder. The cabling device can further include an auxiliary connector that connects to the instrument connector.

According to further aspects, a display device which is able to be coupled to the event data recorder to access the event data stored in the event data recorder is provided to visually display the event data for diagnostic purposes. The data can be downloaded to an external computing device which can include the display device.

In accordance with further aspects, a system for use with an automotive vehicle to facilitate determining the cause of an intermittent failure includes a processor that controls operation of an event data recorder, a recording device that receives real time event data from the vehicle and stores the same for later analysis, and a wire-less transmitter including an actuator that, when actuated by a user, initiates storing of the event data. The recording device can store a predetermined amount of real-time data upon initiation of the event data recorder or can store the contents of a continuous loop of event data.

In accordance with other aspects, a system and method are provided to convey information from a device connected to a vehicle which includes an electronic circuit that flashes an indicator lamp of the vehicle in predetermined patterns under control of the device. The pattern can convey information to the user, such as the device is installed properly or the device is performing a commanded function.

A system and method are further provided for testing a computer-controlled machine which includes a testing device coupled to an electrical system of the machine and a wireless device that activates the testing device. In one embodiment,

the machine is a motor vehicle and the wireless device is mounted within reach of the driver, for example, on a steering mechanism, of the vehicle.

A cabling device and method are further provided for connecting an accessory, such as an automotive car-starter or an automotive vehicle theft alarm, to a machine. The cabling device can include a plurality of contact pins connected to a plurality of wires for inserting into electrical connection points of the machine.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. 1 is a schematic block diagram of an embodiment of an event recorder or data processing device for use with a generic computerized machine control system.

FIG. 2 is a schematic block diagram of another embodiment of the data processing device in a motor vehicle.

FIG. 3 is a schematic block diagram of an embodiment of the data processing device in a photocopier.

FIG. 4 is a schematic block diagram of an embodiment of a separate current-limited power supply for use with independent add-on sensor(s).

FIG. 5 is a schematic diagram of embodiment of a signal conditioning and ESD protection circuit.

FIG. 6 is a schematic block diagram of an embodiment of a multi-channel analog-to-digital converter circuit.

FIG. 7 is a schematic diagram of an embodiment of a cable decoder circuit.

FIG. 8 is a state diagram of an embodiment of the software implemented in an embodiment of the data processing device.

FIG. 9 is a state diagram of an embodiment of the software implemented in a remote computer.

FIGS. 10A-10C show a technique for shock mounting a printed circuit board.

FIG. 11 is a drawing depicting a wireless push-button transmitter equipped with a hook-and-loop fastener strip for attachment to a motor vehicle.

FIG. 12 is a drawing depicting a wireless push-button transmitter installed on the steering wheel.

FIG. 13 is a simplified schematic diagram of a proposed method of controlling an indicator lamp in a motor vehicle or electronically controlled machine wherein the indicator lamp is controlled by means of switching the negative supply voltage to the indicator lamp.

FIG. 14 is a simplified schematic diagram of a proposed method of controlling an indicator lamp in a motor vehicle or electronically controlled machine wherein the indicator lamp is controlled by means of switching the positive supply voltage to the indicator lamp.

FIG. 15 is a drawing of an embodiment of a "universal" cable for use in connecting a vehicular data recorder to any of the electrical systems within a motor vehicle.

FIG. 16 is a drawing of another embodiment of a "universal" cable of the present system, which includes a multi-conductor cable for use with an optional add-on sensor.

FIG. 17 is a drawing of a standard #1 sewing needle.

FIG. 18 is a drawing of a modified #1 sewing needle.

FIG. 19 is a drawing depicting the attachment of a flexible insulated wire to a modified #1 sewing needle.

FIG. 20 is a schematic drawing illustrating the concept of a custom breakout cable for use with a specific electronic control system.

FIG. 21 is a schematic drawing of a cable for use with an add-on sensor.

FIG. 22 is a schematic drawing of an auxiliary cable for use in place of an add-on sensor.

FIG. 23 and FIG. 24 are drawings depicting a method of attaching wires to a vehicular connector consisting of pin-type contacts.

FIG. 25 is a drawing depicting protective jackets installed on the wires of a vehicular connector assembly.

FIG. 26 is a drawing depicting a vehicular connector assembly enclosed within a protective covering.

FIG. 27 is a drawing of a first embodiment of a custom breakout cable.

FIG. 28 is a drawing of a second embodiment of a custom breakout cable.

FIG. 29 is a drawing of a male/female contact with provision for attachment of a wire.

FIG. 30 is a drawing showing two (2) views of a custom breakout connector.

FIG. 31 is a drawing depicting a cutaway view of a section of a custom breakout connector, showing attachment of probe wires on some of the contacts.

FIG. 32 is a drawing depicting an assembled custom breakout connector with multiple probe wires exiting the connector.

FIG. 33 is a drawing depicting a side view of an assembled custom breakout connector with multiple probe wires exiting both sides of the connector.

FIG. 34 is a drawing of a third embodiment of a custom breakout cable.

FIG. 35 is a drawing depicting typical automotive mating connectors, used on computers and wiring harnesses.

FIG. 36 is a drawing illustrating typical automotive connectors that have been wired together to form a feed-through male/female connector.

FIG. 37 is a drawing illustrating a feed-through male/female connector with probe wires attached to form a breakout connector.

FIG. 38 is a drawing depicting the breakout connector of FIG. 37 enclosed within a protective covering.

FIG. 39 is a drawing depicting right-angle socket connectors for use in converting a typical automotive cable connector into a printed circuit (pc) -mounted connector.

FIG. 40 is a drawing illustrating pc-mounted automotive pin and socket connectors mounted back-to-back on a pc board, with probe wires additionally mounted to the pc board to form a breakout connector.

FIG. 41 is a drawing depicting the breakout connector of FIG. 26 enclosed within a protective covering.

DETAILED DESCRIPTION

The system will be explained in conjunction with the drawing in which FIG. 1 illustrates a basic embodiment of an event recorder or data processing device for use with a generic computerized machine control system. This figure designates an exemplary machine incorporating the data processing device. Only those parts of

the machine which are pertinent to this embodiment are shown in FIG. 1 which include the machine power source 116, the machine designated by reference numeral 110, and a computerized control system comprising a machine control computer 112 which connects to a group of sensors, actuators, and indicators 114 in order to monitor and control the functioning of the machine and provide the user with visual indication of the functioning.

The event recorder system comprises signal probe(s) or feed-through connector(s) 120 adapted to provide access to one or more electrical signals existing within the computerized control system 112 / 114, one or more optional independent sensor(s) 122 adapted to generate electrical signals conveying information about one or more physical phenomena within or around the machine 110, an event recorder 130, and a user trigger device 124 adapted to provide the user with a means to control at least one function of the event recorder. The event recorder 130 comprises an analog-to-digital converter circuit 132 coupled to a processor or microprocessor subsystem 134, adapted to sample designated electrical signals from the signal probe(s) or feed-through connector(s) 120 and any optional independent sensor(s) 122. A data storage subsystem 136 is coupled to the microprocessor subsystem 134, which is coupled to a high-speed communications port 138. A power sensing circuit 140 is coupled to the microprocessor subsystem 134 and to a power management circuit 144. The power management circuit 144 is also coupled to the microprocessor subsystem 134 and to a power supply or source 142. An independent external computer 150 may be coupled to the high-speed communications port 138 at appropriate times, to allow the user to transfer recorded data to the external computer 150 and display the recorded data thereon.

In accordance with the present system, at least one and preferably a plurality of signal probes or feed-through connectors 120 and/or independent sensors 122 are employed to couple the analog-to-digital converter circuit 132 to electrical signals which convey information about the functioning of machine 110 and its control system.

The analog-to-digital converter circuit 132 samples one or more electrical signals at predetermined regular intervals, converting the electrical signals to digital data that is a representation of the sampled signal at the specific point in time at

which the sampling occurred. The digital data thus generated is coupled by microprocessor subsystem 134 into the data storage subsystem 136. When event recorder 130 is monitoring and recording the electrical signal activity from one or more signal probe 120 or sensor 122 inputs, the digital data thus generated is transferred to data storage subsystem 136 for a predetermined period (global) of time. At the end of the predetermined period of time, the oldest data begins to be overwritten by the newest data, creating, effectively, an endless-loop recording device. When a pre-programmed trigger event occurs, e.g., machine 110 operation ceases while the machine power source remains active or the user activates user trigger device 124 to initiate an event recording, microprocessor subsystem 134 ceases the data conversion and storage process. The data which had been stored for the fixed period of time preceding the trigger event is now stored in a semi-permanent state until it has been transferred to external computer 150 via the high-speed communications port 138. The high-speed communications port 138 is adapted to provide for the transfer of stored data from event recorder 130 to the external computer 150 for display and analysis.

Power management circuit 144 provides a means whereby event recorder 130 can be partially or fully powered off at such times that machine 110 is powered off, such capability being crucial when the machine utilizes a battery system as its power source. The power management circuit 144 couples machine power source 116 to power supply 142 under control of power sensing circuit 140 and/or microprocessor subsystem 134, thus providing the capability to power event recorder 130 on in response to machine 110 being powered on. The power management circuit also provides the capability for microprocessor subsystem 134 to cause event recorder 130 to remain powered on when machine 110 is powered off, in order that any pending event recorder activity can be completed prior to powering the event recorder off. In order to ensure that the microprocessor subsystem 134 can cause the event recorder 130 to remain powered on when the machine 110 is powered off, it is necessary that power management circuit 144 be coupled to machine power source 116 such that the machine power source will supply power at all times, regardless of the operating state of the machine. Alternatively, a backup battery 238, as illustrated in FIG. 2, can be employed to

provide temporary power in the absence of power from the machine power source 116.

A vehicular embodiment of the present system will be explained with reference to FIG. 2. This figure designates an exemplary vehicle incorporating the system monitoring and recording described above. Only those parts of the vehicle which are pertinent to this embodiment are shown in FIG. 2 which include the vehicular battery 216, the vehicular fuel system designated by reference numeral 218, and a computerized control system comprising a control computer 112 which connects to a group of sensors, actuators, and indicators 114 in order to monitor and control the functioning of the engine and to provide the driver with visual indication of various operating parameters of the vehicle.

The event recorder system comprises signal probe(s) or feed-through connector(s) 120 adapted to provide access to one or more electrical signals existing within the computerized control system 112 / 114, an optional independent fuel pressure sensor 222 adapted to generate electrical signals conveying the pressure within the vehicular fuel system 218, an event recorder 130, and a miniature wireless user-trigger push-button 224. The push-button 224 is adapted to broadcast a coded control signal by way of an antenna 226 connected thereto, which may be externally connected to the wireless push-button or may be contained internally therein, providing the user with a means to control at least one function of the event recorder 130.

The event recorder 130 comprises signal conditioning and ESD protection circuits 234, coupled to an analog-to-digital converter circuit 132. The analog-to-digital converter circuit 132 is coupled to a microprocessor subsystem 134, and adapted to sample designated electrical signals from the signal probe(s) or feed-through connector(s) 120 and the optional fuel pressure sensor 222. A data storage subsystem 136 is coupled to the microprocessor subsystem 134, which is coupled to a high-speed communications port 138. A vehicle power sensing circuit 140 is coupled to the microprocessor subsystem 134 and to a power management circuit 144. The power management circuit 144 is also coupled to the microprocessor subsystem 134, a power supply 142, vehicular battery circuit 216, an optional backup battery 238, and an optional AC-DC converter 240. An independent external

computer 150 may be coupled to the high-speed communications port 138 at appropriate times, to allow the user to transfer recorded data to the external computer 150 and display the recorded data thereon. An antenna 228 is coupled to a wireless user-trigger receiver 230, adapted to receive and decode the coded control signal broadcast by antenna 226. The wireless user-trigger receiver has its output connected to microprocessor subsystem 134. In alternative embodiments, push-button 224 is hard-wired to the microprocessor subsystem 134 for controlling at least one function of the even recorder 130.

In accordance with the present system at least one and preferably a plurality of signal probe(s) or feed-through connector(s) 120 and an optional fuel pressure sensor 222 are employed to couple analog-to-digital converter circuit 132 to electrical signals which convey information about the functioning of the engine and its control system.

The analog-to-digital converter circuit 132 samples one or more electrical signals at predetermined regular intervals, converting the electrical signals to digital data that is a representation of the sampled signal at the specific point in time at which the sampling occurred. The digital data thus generated is coupled by microprocessor subsystem 134 into the data storage subsystem 136. When event recorder 130 is monitoring and recording the electrical signal activity from one or more signal probe 120 inputs and/or the optional fuel pressure sensor 222 input, the digital data that is generated is transferred to the data storage subsystem 136 for a pre-determined period of time. At the end of the pre-determined period of time, the oldest data begins to be overwritten by the newest data, creating, effectively, an endless-loop recording device. When a pre-programmed trigger event occurs, e.g., the engine stalls while the ignition remains on, the vehicular computer 112 activates the "Check Engine" or similar indicator, or the user presses the wireless user-trigger push-button 224 to initiate an event recording, microprocessor subsystem 134 ceases the data conversion and storage process.

The data which had been stored for the fixed period of time preceding the trigger event is now stored in a semi-permanent state until it has been transferred to external computer 150 via to the high-speed communications port 138. In one embodiment, sufficient data storage will be implemented so as to allow one or more

additional events to be recorded using a different section of data storage subsystem 136, providing for the monitoring, recording, and storing of multiple events before transferring the stored data to the external computer 150 for display and analysis.

In one embodiment, in order to provide a visual indication to the user that the trigger signal from miniature wireless user-trigger push-button 224 has been successfully received and decoded by wireless user-trigger receiver 230 and that an event recording has been stored in data storage subsystem 136, microprocessor subsystem 134 utilizes visual indicator driver 232 to flash the vehicle "Check Engine" indicator for several seconds. Thus, a feedback system is provided to alert the user that the event recorder 130 is installed and working properly.

High-speed communications port 138 is adapted to provide multiple functions of the present system, including but not limited to the transfer of stored data from event recorder 130 to external computer 150 for display and analysis, the transfer of software upgrades to event recorder 130 for the purpose of adding new and/or improved functionality, and the transfer of configuration information to event recorder 130 to allow the user to specify and customize functionality. Optional AC-DC converter 240 can be connected to power management circuit 144 when it is desirable to operate event recorder 130 in isolation from a motor vehicle, for purposes of utilizing any of the functionality available through the high-speed communications port 138.

In accordance with principles of the present system, physical phenomena which are not monitored by the computer system(s) within a vehicle, but which are deemed to have significance in analysis of the performance of the vehicle, can be monitored by means of one or more independent sensors 222 which are coupled to the vehicle for use with event recorder 130. Examples of physical phenomena which are not monitored by motor vehicle computer systems are the pressure in the fuel system and the line pressure in the automatic transmission, which are phenomena of particular interest to a service technician in the evaluation of vehicular performance problems. In one embodiment, an electronic pressure sensor is coupled to the vehicular fuel system, or to the automatic transmission, to provide a means to monitor the pressure therein. Power for the pressure sensor is provided by event recorder 130 and the electrical signals produced by the pressure sensor are coupled

to the event recorder 130 for conversion and recording. Alternatively, in a different embodiment, two separate pressure sensors can be used to monitor both fuel pressure and transmission line pressure simultaneously. Other phenomena which are deemed of importance can be monitored and recorded by similar means through the appropriate use of independent add-on sensors.

A cable decoder circuit 236 is employed to provide a means for microprocessor subsystem 134 to determine the specific input cable which is connected to event recorder 130. Thus, a variety of input cables, using a variety of sensor probe(s) and feed-through connector(s) 120 can be constructed. Such cables employing one or more of the feed-through connectors 120 can be constructed so as to connect specific electrical signals from within a specific vehicle or a specific class of vehicles to specific signal inputs of event recorder 130. Installation of appropriate wire jumpers within the connector which connects to event recorder 130 will allow cable decoder circuit 236 to determine which cable has been connected, allowing event recorder 130 to configure signal conditioning circuits 234 appropriately for the supplied input signals, as well as allowing for automatic identification of input signals without user intervention.

A crucial requirement for electronic devices which are installed in motor vehicles, whether permanently or temporarily, and powered by the battery systems therein, is that they consume little or no power when the vehicle is inactive, in order to avoid excessive drain on the vehicular battery during the inactive period. In one embodiment of the present system, event recorder 130 will initiate normal operation, i.e., constant data conversion and recording, and power consumption when the motor vehicle becomes active, e.g., when the ignition switch is set to the "on" position. A vehicular power sensing circuit 140 couples vehicle power to power management circuit 144, which activates power supply 142 to provide power to event recorder 130 and the circuits of which it is comprised.

When the vehicle becomes inactive, microprocessor subsystem 134 controls power management circuit 144 to maintain power output from power supply 142 only for a minimum period of time required to allow event recorder 130 to complete any pending activity associated with normal operation, after which microprocessor subsystem 134 will cause power management circuit 144 to deactivate power supply

142 such that event recorder 130 will cease normal operation and the power consumption will be reduced to a minimum.

Alternatively, in the event that the microprocessor subsystem 134 has the capability to implement a low power mode in which its power consumption is sufficiently reduced so as to provide an acceptably low power drain on the vehicular battery 216 the power management circuit 144 can be configured to remove power from any and all circuits that are not required to maintain the microprocessor subsystem in the low power mode. In the event that data storage subsystem 136 requires constant power in order to maintain stored data within the data storage subsystem, the power management circuit 144 will ensure that constant power is made available to the data storage subsystem.

An exemplary non-vehicular embodiment of the present system will be explained with reference to FIG. 3. This figure designates a monitoring and recording system for use with a computerized control system within a photocopier. Only those parts of the photocopier which are pertinent to the embodiment are shown in FIG. 2 which include the photocopier power source 116, the photocopier designated by reference numeral 110, and a computerized control system comprising a machine control computer 112 which connects to a group of sensors, actuators, and indicators 114 in order to monitor and control the functioning of the photocopier and provide the user with visual indication of the functioning.

The event recorder system comprises signal probe(s) or feed-through connector(s) 120 adapted to provide access to one or more electrical signals existing within the computerized control system 112 / 114, one or more optional independent add-on sensor(s) 122 adapted to generate electrical signals conveying information about one or more physical phenomena within or around the photocopier, an event recorder 130, and a user-trigger push-button 242. In one embodiment push-button 242 is a simple push-button adapted for temporary attachment to an external surface of the photocopier 110, adapted to provide the user with a method to control at least one function of the event recorder 130. The event recorder 130 comprises signal conditioning and ESD protection circuits 234, coupled to an analog-to-digital converter circuit 132. The analog-to-digital converter circuit is coupled to a microprocessor subsystem 134, and adapted to sample designated electrical signals

from the signal probe(s) or feed-through connector(s) 120 and any optional independent add-on sensor(s) 122. A data storage subsystem 136 is coupled to the microprocessor subsystem 134, which is coupled to a high-speed communications port 138. A power sensing circuit 140 is coupled to the microprocessor subsystem 134 and to a power management circuit 144. The power management circuit 144 is also coupled to the microprocessor subsystem 134, a power supply 142, the machine power source 116, an optional backup battery 238, and an optional AC-DC converter 240. An independent external computer 150 may be coupled to the high-speed communications port 138 at appropriate times, to allow the user to transfer recorded data to the external computer 150 and display the recorded data thereon. A user-trigger input circuit 244 isolates and couples the input from user-trigger push-button 242 to microprocessor subsystem 134.

In accordance with the present system, at least one and preferably a plurality of signal probes or feed-through connectors 120 and/or independent sensors 122 are employed to couple analog-to-digital converter circuit 132 to electrical signals which convey information about the functioning of photocopier 110 and its control system.

Sampling, data conversion, and data storage are accomplished as described above. When a pre-programmed trigger event occurs, e.g., machine operation ceases while the machine power source remains active or the user activates the user-trigger push-button 242 to initiate an event recording, microprocessor subsystem 134 ceases the data conversion and storage process. The data which had been stored for the fixed period of time preceding the trigger event is now stored in a semi-permanent state until it has been transferred to external computer 150 coupled to the high-speed communication port 138. In one embodiment, in order to provide a visual indication to the user that the trigger signal from user-trigger push-button 242 has been processed by user-trigger input circuit 244 and applied to microprocessor subsystem 134, and that an event recording has been stored in data storage subsystem 136, the microprocessor subsystem utilizes visual display / indicator driver 246 to apply appropriate visual display or indicator control signals to visual display or indicator(s) 248. The visual display or indicator(s) 248 can range, depending on the specific application, from a simple Light Emitting Diode (LED)

which is flashed for several seconds when an event is stored, to a multiple LED array conveying additional information, to a multi-character display which provides information such as number of events stored automatically, number of user-initiated events stored, condition of backup battery, etc. In one embodiment, the visual display or indicator(s) 248 is included in a common package with user-trigger push-button 242.

High-speed communications port 138 is adapted to provide for the transfer of stored data from event recorder 130 to external computer 150 for display and analysis, as well as providing the additional functionality described earlier.

In accordance with principles of the present system, physical phenomena which are not monitored by the computer system(s) within a photocopier, but which are deemed to have significance in analysis of the performance of the photocopier, can be monitored by means of one or more independent add-on sensors 122 which are coupled to the photocopier for use with event recorder 130. As required and/or desired, appropriate power for the independent add-on sensor(s) can be provided by the event recorder 130, in order to increase the ease-of-use of the independent add-on sensor(s) in conjunction with the event recorder.

A cable decoder circuit 236 is employed to provide a means for microprocessor subsystem 134 to determine the specific input cable which is connected to event recorder 130 as described earlier for the automotive embodiment. Power control can also be implemented in this embodiment as described earlier for the automotive embodiment. It is noted that principles of the present system can easily be adapted for use with any type of computer-controlled equipment which is experiencing intermittent anomalies.

According to principles of the present system, event recorder 130 can supply the power required by independent add-on sensor(s) 122 which are connected to a machine in order to measure phenomena which are not routinely measured by a computerized machine control system incorporated within the machine. Since the power for the add-on sensor(s) must be brought outside of the event recorder 130, the opportunity exists for the power to be intentionally or accidentally connected in such a way as to place an excessive load or short circuit on a power supply which forms the source of the power. In order to prevent such excessive load from drawing

excessive current, which could pose a safety hazard, and/or further risk disruption of the function of the event recorder 130, and which could further risk damage to the event recorder, the present system provides for the use of a separate, current-limited power supply 254 as the power source for use with the add-on sensor(s).

FIG. 4 illustrates details of an embodiment of the separate, current-limited power supply implemented as part of the vehicular event recorder embodiment illustrated in FIG. 2. Only that part of the vehicle which is pertinent to this embodiment of the separate current-limited power supply is shown in the drawing, which is the vehicular battery 216. Only those parts of the event recorder system which are pertinent to this embodiment of the separate current-limited power supply are shown in the drawing and they include the event recorder 218, fuel pressure sensor 222, additional independent add-on sensor 122, microprocessor subsystem 134, power management circuit 144, power supply 142, signal conditioning and ESD protection 234, and analog-to-digital converter 132. The power supply 142 comprises multiple independent power sources, consisting of a +5 Volt supply 250 for microprocessor subsystem 134, a +5 Volt supply 252 to provide power for the remaining event recorder circuits, and a +5 Volt / 0.2 Amp supply 254 to provide power for the fuel pressure sensor 222 and/or the additional independent add-on sensors 122.

Each of the independent power sources is individually controlled by power management circuit 144. Thus microprocessor subsystem 134 has the ability, through the power management circuit, to remove power from external sensors 122 /222 by deactivating +5 Volt supply 254 and/or remove power from the remaining event recorder circuits by deactivating +5 Volt supply 252, at such times that the sensors and/or event recorder circuits do not need to be operational. Additionally, the use of a separate supply for external sensors prevents disruption of the functioning of the remainder of event recorder 130 in the event that excessive loading is applied to the separate supply.

The +5 Volt / 0.2 Amp supply 254 is coupled through signal conditioning and ESD protection circuit 234 to analog-to-digital converter 132, providing a means for microprocessor subsystem 134 to determine the output level of the +5 volt / 0.2 Amp supply. In the event that the supply is excessively loaded, which will

result in the output level being unacceptably low, the microprocessor subsystem 134 can control power management circuit 144 to disable the supply. In the event that fuel pressure sensor 222 and/or any additional independent add-on sensor operates ratiometrically, i.e., the sensor output is a ratio of the supply voltage which is coupled to the sensor, the +5 Volt / 0.2 Amp supply 254 can be sampled and converted to digital data by analog-to-digital converter 132, thus providing an accurate reference for use in determining the correct value represented by the output of the ratiometric sensor(s).

The +5 Volt / 0.2 Amp supply 254 can be limited to a maximum short-circuit current of 0.2 Amp, which will prevent safety risks and will prevent damage to the event recorder in the event that excessive loading or a short circuit is applied to the +5 Volt / 0.2 Amp supply. The +5 Volt / 0.2 Amp supply 254 additionally contains thermal overload protection, which will prevent damage to the supply in the event of excessive current drain due to excessive loading or short circuit.

FIG. 5 illustrates an embodiment of a circuit providing ESD protection and signal conditioning for an analog input 300. The analog input is applied to spark gap 302, which is coupled to circuit ground 304, and to resistor 306. The spark gap 302 and the resistor 304 are designed such that an electrostatic discharge (ESD) at analog input 300 will spark across the spark gap at a significantly lower voltage than would be required to spark across the resistor. Signal diodes 308, 310 act with resistor 306, which acts as a current limit, to protect amplifier 316 and capacitor 314 from excessive and damaging electrical voltages produced by ESD or application of excessive voltage to analog input 300, by clamping the voltage at the amplifier at a maximum of a diode-drop above power supply 332 and at a minimum of a diode-drop below circuit ground 304. Resistor 312 acts with resistor 306 to divide the voltage at the analog input 300 to ensure that the dynamic range of amplifier 316 is not exceeded when the maximum specified input voltage exists at the analog input. Capacitor 314 acts with resistor 312 and capacitor 320 acts with resistor 322 to provide noise filtering. Resistors 324, 326 act with resistor 322 to produce appropriate gains in amplifier 316 when coupled to signal ground by switches 328, 330. Microprocessor subsystem 134, not shown in this figure, controls the gain of amplifier 316 by controlling switches 328, 330.

FIG. 6 illustrates an embodiment of analog-to-digital converter 132. A plurality of input signals are coupled from signal conditioning and ESD protection circuits 234 to a multiplexer 256, which presents each of the input signals in turn to sample and hold / analog-to-digital converter 258. Digital data 266, representing the sampled analog signals, is coupled from the sample and hold / analog-to-digital converter to a FIFO (first-in-first-out memory device) 270 and from the FIFO to microprocessor subsystem 134. A programmable clock source 262 couples a periodic converter clock signal 268, controlled by quartz crystal 264 for high frequency stability, to a data conversion controller 260 and to the microprocessor subsystem 134. The data conversion controller 260 is coupled to and controls the function of multiplexer 256, sample and hold / analog-to-digital converter 258 and FIFO 270.

At the start of data sampling and conversion, each of one or more data inputs is connected in turn through multiplexer 256 to sample and hold / analog-to-digital converter 258, converted to digital data and coupled into FIFO 270, under control of data conversion controller 260. Thereafter, the data conversion controller 260 repeats this sequence upon the occurrence of each converter clock signal 288. Microprocessor subsystem 134 initiates converted data requests 272 to the data conversion controller 260 upon the occurrence of the converter clock signal, whereupon FIFO 270 couples digital data 266 to the microprocessor subsystem under control of the data conversion controller. The converted data requests 272 are issued in sufficient quantity so as to ensure that the stored data in the FIFO 270 is maintained at an amount sufficiently low so as to prevent overflow of the FIFO 270 and the resultant loss of digital data.

According to principles of the present system, the number of analog inputs can easily be expanded by implementing multiplexer 256 using a device with a greater number of inputs, while ensuring that sample and hold / analog-to-digital converter 258 is fast enough to convert the additional analog inputs to digital data within a single converter clock period. Alternatively, the number of analog inputs can be expanded by duplicating the data conversion subsystem comprised of multiplexer 256, data conversion controller 260, sample and hold / analog-to-digital converter 258, and FIFO 270.

FIG. 7 illustrates an embodiment of cable decoder 236. Two code inputs are shown, providing the ability to decode up to three different input cables, since a total lack of wire jumpers at the code inputs is interpreted as "no cable connected". The number of allowable input cables can be expanded by replicating the circuits illustrated in FIG. 7

A cable, not shown in this figure, coupled to input connector 350 has one or more wire jumpers installed so as to couple one or more code inputs 352, 354 to a ground pin 356 on the input connector, the ground pin coupling to circuit ground 380. In the event that code input 352 is not coupled to ground pin 356, power supply 382 is coupled through resistors 362, 364 to buffer 378. Conversely, in the event that the code input 352 is coupled to the ground pin 356, circuit ground 380 is coupled through resistor 364 to the buffer 378. Code input 354 operates on the same principle, in conjunction with resistors 370, 372. Microprocessor subsystem 134, not shown in this figure, couples to cable decoder 236 through buffer 378.

The buffer 378 is protected from excessive input voltage and from ESD by the circuits consisting of spark gaps 358, 360, resistors 364, 372, and signal diodes 366, 368, 374, 376. The principles of these circuits are explained in the description of FIG. 5 (Signal Conditioning and ESD Protection Circuit).

FIGS. 10A to 10C illustrate a method of shock-mounting circuit boards that is implemented in an embodiment of the present system, in order to minimize the possibility of failures due to shock and vibration, most especially in vehicular environments. FIG. 10A illustrates the preparation of a printed circuit board 710, which is represented by a cutaway side view. The preparation consists of the installation of a rubber grommet or first cushion member 712 into a hole, which has been specifically designed for this purpose, in the printed circuit board 710.

FIG. 10B illustrates the specifics of shock-mounting the printed circuit board 710 which has been so prepared into a target housing 714, also represented by a cutaway side view. A screw 716, for example, a 40 x ½ inch screw 716 is inserted through a mounting hole in the housing 714, then through a second rubber grommet or cushion member 722, then through grommet 712, which was previously installed in the printed board, then through a washer 718, for example, a #4 flat washer, and finally into a hex nut 720, for example, a 4.40 hex nut. Threadlocker is used to

ensure that the hex nut 720 will not loosen from the screw 716 in the event of severe vibration.

FIG. 10C illustrates the completed assembly. Printed circuit board 710 is now isolated from housing 714 and from mounting screw 716 by rubber grommets 712, 722, such that any shock or vibration that is coupled to the housing 714, and thereby to the mounting screw, will be significantly attenuated by the rubber grommets before affecting the printed circuit board.

In one embodiment, screw 716 is replaced by a threaded post, for example, a 4-40 x ½ inch threaded post, which is permanently pressed into housing 714, with second rubber grommet 722, then the printed circuit board containing grommet 712, then #4 flat washer 718, and finally 4-40 hex nut 720 installed onto the threaded post, thereby simplifying the assembly of the printed circuit board into the housing.

An important event trigger when analyzing intermittent failures in a motor vehicle is an engine stall. This condition can be detected by monitoring for loss of normal engine function while the vehicle ignition system remains energized, because the normal engine function is normally terminated by the act of de-energizing the ignition system. In modern computerized engine control systems, the ignition control circuits generate one or more control or reference signals which are not present until the engine is operating, and which cease when the engine ceases operating due to a stall or due to the ignition system being de-energized. The following technique can be utilized to detect a vehicle stall:

1) Connect the ignition voltage to an appropriate input to event recorder 130 and an appropriate ignition-generated signal to another appropriate input to the event recorder.
2) Monitor the ignition-generated signal to determine the point in time at which the engine is operating.
3) Continue monitoring the ignition-generated signal to determine the point in time at which the engine ceases operating.
4) At the point in time at which the engine ceases operating, check the state of the ignition voltage to determine whether the ignition system is energized (this constitutes a stall event)

or whether the ignition system is de-energized (this constitutes a normal shut-down).

This technique can be implemented with a combination of hardware and software, wherein the hardware produces register values corresponding to the physical states of the ignition-generated signal and the ignition voltage and the software polls the register values to determine the physical states. Alternatively, event recorder 130 can contain a hardware circuit that is adapted to produce a trigger signal only in the event that the ignition-generated signal ceases while the ignition system remains energized.

Similar techniques can be adapted for use with other types of computer-controlled equipment, utilizing appropriate signals which are present only when the equipment is operating normally, in order to detect abnormal termination of the proper operation of the equipment.

The system which forms the subject matter of this application can be readily implemented with state-of-the-art devices. Thus, readily available single-board computers, e.g., of the type which are presently utilized in numerous special-purpose computer-controlled devices, may serve as the microprocessor subsystem 134. Examples of such single-board computers appear on pages 36, 37, and 59 of the February 1998 issue of "Circuit Cellar INK" magazine. Many commercially available single-board computers provide the functionality of a data storage subsystem 136 and a high-speed communications port 138, with some also providing an integral analog-to-digital converter circuit 132.

Alternatively, a separate analog-to-digital converter circuit 132 can be implemented and coupled to microprocessor subsystem 134, for example, as shown on pages 91 through 94 of "Data Acquisition Techniques Using Personal Computers" by Howard Austerlitz, Copyright 1991 by Academic Press, Inc., the contents of which are incorporated herein by reference. Microprocessor subsystem 134 could alternatively be implemented by using multiple microprocessors and/or microcontrollers. A first microcontroller can be used to control analog-to-digital converter 132 while a second microcontroller or microprocessor can be used to control data storage subsystem 136 and high-speed communications port 138. The first microcontroller would couple output data from the analog-to-digital converter

132 to the second microcontroller, which would the output data to the data storage subsystem and/or the high-speed communications port as appropriate.

Signal probes 120 can be implemented by utilizing individual wire-piercing probes such as those which are commercially available for use as accessories for electronic multi-meters. These probes, by design, inflict damage to the insulation of the wires that are probed, and a great deal of care is required to ensure reliable connection to the inner conductor of the pierced wire. Due to the mechanical complexity of these probes, they are relatively costly. Alternatively, feed-through coupling connectors can be inserted between a machine control computer 112 and sensors/actuators/indicators 114 and adapted to couple the desired signals into event recorder 130. For automotive embodiments, the feed-through coupling connectors can take the form of commercially available "breakout box" harnesses which are readily available and widely used in automotive diagnosis and repair. In one embodiment, one of the breakout cables of the present system is utilized. For non-automotive embodiments, similar feed-through connector harnesses can be developed and implemented.

A user trigger device 124 may take the form of a simple push-button switch which is coupled into event recorder 130, such that pressing the switch will act as a trigger to cause an event to be recorded. Alternatively, a wireless user-trigger push-button 224 may take the form of a wireless remote control device, similar in form to a wireless garage door opener or a wireless doorbell.

In accordance with principles of the present system, a data storage subsystem 136 can be implemented with magnetic mass storage devices of the type commonly used in modern computers, most notably in small "lap-top" portable computers, providing a large amount of data storage at relatively low cost. Alternatively, solid state memory devices, including, but not limited to, flash and static RAM (SRAM), may be used in the event that a smaller amount of data storage is required, implementing a data storage system that is smaller and avoids the mechanical and environmental limitations inherent in magnetic storage devices.

In a first embodiment of the present system, data storage subsystem 136 is implemented as a first memory which exists within the dynamic RAM (DRAM) supplied as part of a single-board computer and a second memory which exists

within a flash memory (FLASH) supplied as part of the single-board computer. The first memory is used for temporary storage of data while waiting for a trigger event. Upon the occurrence of a trigger event, microprocessor subsystem 134 transfers data from the first memory to the second memory for semi-permanent storage until such time as the data is transferred to external computer 150. An alternative embodiment may use a single memory implemented in static RAM, with the memory used for temporary, endless-loop data storage while waiting for a trigger event, upon which event the memory will be maintained as semi-permanent storage until such time as the data existing within the memory is transferred to external computer 150. The memory can be subdivided to allow storage of multiple events prior to transfer of the contents of the memory to the external computer.

A high speed communications port 138 can be implemented through various means, including but not limited to high speed serial communications, bi-directional parallel communications, wireless infra-red data communications, etc. At such time as the new high-speed USB (Universal Serial Bus) and FireWire (IEEE P1294 Standards Serial Interface) technologies are widely implemented, they will provide an advantageous communications means, due to a high communications speed and the ease that they provide for coupling multiple peripheral devices to a computer. Also, as use of local area networks and the internet increases, it may become advantageous to implement high speed communications port 138 as a network node, using a network protocol such as ethernet to connect directly to a local area network, or as an internet appliance, using an internal modem to connect directly to the internet.

External computer 150 can take the form of a desk-top PC-compatible computer, providing the advantage of plentiful data processing power and high quality graphics display. Alternatively and more preferably, the external computer 150 can be a portable lap-top computer, as such computers of modern vintage provide data processing power and graphics capability which rivals that of desk-top computers while allowing a technician to transfer and display data in close proximity to the machine 110, typically without the requirement of removing event recorder 130 from the machine.

Required power supply circuits within power supply 142 can be implemented through the use of any of the many commercially available monolithic or modular power supply circuits which are appropriate for the voltage and current requirements of the specific implementation of the event recorder.

In accordance with principles of the present system, microprocessor subsystem 134 includes permanent memory for a custom software program. The software program is executed by the microprocessor subsystem in order to implement the functionality of event recorder 130.

FIG. 8 illustrates the multiple states in which a first embodiment of the software can exist and the conditions which cause a transition from one state to another, and is explained in conjunction with the block diagram of FIG. 2. Upon initial power up of event recorder 130, which occurs when power is applied to power sensing circuit 140 or when power is applied by means of optional AC-DC converter 240, the active state is initialization state 510. Upon completion of initialization, the state transitions to "wait for communications" state 516 in response to power sense OFF 550, which condition may exist when power is applied by means of optional AC-DC converter 240, or the state transitions to data collection state 512 in response to power sense ON 552.

Data collection state 512 is the usual state of event recorder 130. When a trigger is activated 560, the state transitions from data collection state 512 to event storage state 514. When event storage is completed 562, the state transitions back to data collection state 512 UNLESS loss of power 554 has occurred, in which case the state transitions to "wait for communications" state 516. While in data collection state 512, activation of a communications interrupt 566 will cause a transition to communications idle state 518, in which communications through high-speed communications port 138 has been initiated but no active communications state has yet been initiated. Loss of power 554 or detection of power sense OFF 550 will cause a transition from the data collection state 512 to "wait for communications" state 516.

Upon entering the "wait for communications" state 516, microprocessor subsystem 134 relinquishes control of power management circuit 144, in which case event recorder 130 will only remain active when power is applied to power sensing

circuit 140 (power sense ON 552), in which case the state transitions back to data collection state 512, or when power is applied by means of optional AC-DC converter 240. In the event that the "wait for communications" state exists without power input by means of the AC-DC converter 240, the event recorder 130 will automatically power down 558. While the "wait for communications" state 516 exists, activation of a communications interrupt 566 causes a transition to communications idle state 518.

Communications idle state 518 exists until such time as an active communication state is initiated or until communication is terminated. Upon termination of communications 582, the state transitions to "wait for communications" state 516. Upon initiation of stored event transfer 568, the state transitions to stored event transfer state 522 in which the user can transfer one or more events from data storage subsystem 136 to external computer 150. Upon completion of stored event transfer 570, the state transitions back to communications idle state 518, from which another communication state can be initiated or communications can be terminated 582.

Upon initiation of configuration transfer 572, the state transitions to configuration transfer state 520 in which the user can download the current configuration of event recorder 130 to external computer 150 or upload a new/updated configuration from the external computer to the event recorder 130. Note that the configuration is implemented by the event recorder 130 only when the event recorder is coupled to a "general purpose" input cable consisting of one or more signal probes 120 which can be connected to any of a multitude of electrical signals within a vehicle. When coupled to a special coded cable which has been designed to connect to specific electrical signals, the event recorder 130 is automatically configured for operation with the cable, regardless of the current user-specified configuration. Upon completion of configuration transfer 574, the state transitions back to communications idle state 518.

Upon initiation of real-time data collection and transfer 576, the state transitions to real-time data collection / transfer state 524 in which the user can transfer, for immediate viewing on external computer 150, digitized data for one or more input signals as they are actually occurring. Upon termination of real-time

data collection and transfer 578, the state transitions back to communications idle state 518.

In accordance with principles of the present system, external computer 150 will be used to implement the display of recorded data. Commercially available software, provided by numerous manufacturers of data acquisition equipment, can be implemented for the purpose of displaying the data. Alternatively, custom software may be created in order that new features which are deemed advantageous to the present system can be provided. The custom software may also provide functions pertaining to configuration of the event recorder 130, as well as data transfer functionality, in a single integrated program so as to maximize ease of use. Using state of the art software techniques, external computer 150 could potentially be programmed to analyze the stored data and assist the service technician in identifying performance problems, abnormalities, the cause of an intermittent failure, etc., thereby allowing less trained technicians to successfully utilize the event recorder system.

FIG. 9 illustrates the multiple states in which a first embodiment of custom software for implementation in the external computer can exist and the conditions which cause a transition from one state to another. Upon startup of the software, the initial state is main menu state 610, in which the user can select from among several activities. Upon user initiation of event data display 652, the state transitions to event data display state 612, in which the user can select and display any of at least one events which are accessible to the external computer, e.g., residing on a connected hard drive, floppy disk, CD ROM, etc. The event data display state provides functionality to re-create and display the electrical signals which were sampled and converted to digital data by event recorder 130, and to allow viewing of the electrical signals at differing time resolutions to facilitate the interpretation of the electrical signals, scrolling of the electrical signals to view activity at different points in time, and printing of the current display using a printer connected to the external computer. While in event data display state 612, user initiation of printing of the current display 682 causes the state to transition to print current display state 630. Upon termination of the printing activity 684, the state transitions back to event data

display state 612. Upon termination of event data display 654, the state transitions back to main menu state 610.

Upon user initiation of configuration creation 656, the state transitions to configuration creation state 614, which provides functionality including, but not limited to, allowing the user to assign labels to any or all of the inputs to event recorder 130, to specify the voltage input range of the inputs, to assign identifying information pertaining to the vehicle in which the event recorder will be installed, to save a configuration for transfer to the event recorder, and to modify an existing configuration. Upon termination of configuration creation 658, the state transitions back to main menu state 610.

Upon user initiation of any function that requires communications 660, the state transitions to communications idle state 616, which provides functionality for establishing communications with event recorder 130 and exists until such time as an active communication state is initiated, an unsuccessful communication attempt is intentionally aborted or times out, or successful communication is completed. In the event that an active communication state is initiated and then unintentionally terminated, functionality is provided within the communications idle state to attempt to re-establish the active communication state until the attempt is intentionally aborted or times out. Upon termination of communications 662, the state transitions back to main menu state 610.

When communication with the event recorder 130 is successfully established in response to the user initiating a configuration upload 664, the state transitions to configuration upload state 620, which provides functionality for uploading a user-specified configuration from remote computer 150 to the event recorder. Upon termination of configuration upload 668, the state transitions back to communications idle state 616.

When communication with the event recorder 130 is successfully established in response to the user initiating a configuration download 670, the state transitions to configuration download state 622, which provides functionality for downloading the current configuration from the event recorder to remote computer 150. Upon termination of configuration download 672, the state transitions back to communications idle state 616.

When communication with the event recorder 130 is successfully established in response to the user initiating a stored event data download 674, the state transitions to stored event data download state 624, which provides functionality for downloading one or more stored events from the event recorder to remote computer 150. Upon termination of stored event data download 676, the state transitions back to communications idle state 616.

When communication with the event recorder is successfully established in response to the user initiating the download and display of real-time data 678, the state transitions to download and display real-time data state 626, which provides functionality for downloading real-time or quasi-real-time digitized data from the event recorder and for using the digitized data to recreate and display, on remote computer 150, the electrical signals which are being sampled and converted to digital data by the event recorder, and to allow viewing of the electrical signals at differing time resolutions to facilitate the interpretation of the electrical signals. Upon termination of real-time data download and display 680, the state transitions back to communications idle state 616.

According to principles of the present system, the display of recreated electrical signals are presented on a computer monitor such that each signal will occupy its own area of the display screen on the computer monitor. In a first embodiment, the display screen is divided into 16 horizontal channels, representing the 16 possible electrical signals recorded and stored by event recorder 130. The recreated electrical signals are displayed in time synchronization, i.e., a vertical line drawn through any point on the display represents the same point in time for all signals intersected by the vertical line. The time synchronization ensures that an observer can readily determine the time relationships between any and all signals.

As a further aid to interpretation of the electrical signals, color is used to differentiate various signal states. In one embodiment, the display background is rendered in a light gray. For each channel, the ground reference level is displayed in black and the full-scale level is displayed in red. As any electrical signal is recreated on the display, three colors are used in the presenting the electrical signal. When a sample of the electrical signal is below a first specified value, close to the ground reference, the sample is recreated in blue. When a sample of the electrical signal is

above a second specified value, close to full scale, the sample is recreated in green. When a sample of the electrical signal is between the first and second specified values, the sample is recreated in white.

As a further aid to interpretation of the electrical signals, the user can change the time period represented by a full-screen display of the electrical signals. In a first embodiment, the user can choose to have the display show time durations from 1/16 of a second to 1 second, allowing the user to scroll through signals rapidly at the longer duration, then switch to shorter durations to observe greater detail in an area of interest.

Alternative embodiments of this software allow the user to select the number of channels to display at one time, which provides better resolution when fewer channels are displayed. The user is also able to select which channels to display.

The wireless push-button in the present system is implemented by use of a miniature key-fob type wireless transmitter, which has a single large push-button or actuator. The push-button provides a distinct audible and tactile click when pressed, providing the user with the desired feedback. In order that the user can press the push-button without diverting his/her eyes from the road ahead and without removing his/her hands from the steering wheel, the wireless push-button transmitter is mounted within reach of the user. In one embodiment, the wireless push-button transmitter is mounted on the vehicle steering wheel, using a hook-and-loop fastener strip in order that there is no damage to the vehicle. In other embodiments, the wireless push-button transmitter is mounted on the steering mechanism of the vehicle to be monitored, such as on the handle bar of a motorcycle. Further, the wireless push-button transmitter is mounted such that its body is located towards the inside of the steering wheel, minimizing the possibility of hand injury in the event that the steering wheel spins rapidly.

An embodiment of the wireless user-trigger push-button will be described in conjunction with FIG. 11 and FIG. 12. FIG. 11 illustrates a miniature "key-fob" type wireless transmitter 224, of the type commonly used for garage door openers and other simple remote control functions. Attached to the wireless transmitter is a ½ inch by 8 inch strip of hook-and-loop fastener strip 815, constructed such that one surface of the hook-and-loop fastener strip consists of hooks that will adhere to the

loops on the other surface of the hook-and-loop fastener strip. FIG. 12 illustrates a method of attaching wireless transmitter 224 to a motor vehicle steering wheel 817 by means of the hook-and-loop fastener strip, which has been wrapped around the steering wheel and back over itself, such that the top and bottom surfaces of the hook-and-loop fastener strip adhere to each other and hold the wireless transmitter securely in place. Note the placement of the wireless transmitter so that it resides on the INSIDE surface of the steering wheel, positioned much like the Push-To-Talk switch for an aircraft radio is positioned on an aircraft yoke.

In an embodiment, one or more of the malfunction indicator lamps that are integral to a motor vehicle or other machine control system are utilized in a feedback system to provide a visual indication of vehicular event recorder status. In alternative embodiments, other feedback means can be implemented, for example, the actuation of a audible device such as a chime. In the event that the vehicular event recorder has failed, does not have an effective connection to the vehicular power system, or is in the start-up initialization process, the malfunction indicator lamp is maintained in a steady "active" state until such time as the problem is corrected or the initialization is completed. In the event that the vehicular event recorder is working normally, the malfunction indicator lamp is flashed briefly at fixed intervals, the intervals being approximately 4 seconds in one embodiment.

In the event that the vehicular event recorder is in the process of recording an event, the malfunction indicator lamp is flashed at a 50% duty cycle and at a fixed frequency, the fixed frequency being approximately 3 Hz in one embodiment. In the event that the vehicular event recorder has not been properly configured prior to installation into a motor vehicle or other machine control system, but is otherwise functioning normally, the malfunction indicator lamp is flashed at a 50% duty cycle and at a fixed frequency, the fixed frequency being significantly and obviously different than the fixed frequency utilized when the vehicular event recorder is in the process of recording an event, the fixed frequency further being approximately 0.25 Hz in one embodiment. As the foregoing discussion demonstrates, the present system provides for a multitude of different status conditions to be conveyed to the user by means of different flash patterns and different flash frequencies.

A method of utilizing the malfunction indicator lamp to provide visual status indication to the user will be described in conjunction with FIG. 13 and FIG. 14. FIG. 13 is a simplified schematic diagram in which only those parts of a motor vehicle 810 and a vehicular data recorder 812 that are pertinent to one embodiment of the present system are shown. The positive terminal of a malfunction indicator lamp 818 is connected to the vehicle switched ignition voltage 816 such that power is available to the malfunction indicator lamp only when the ignition in the motor vehicle is switched on.

The negative terminal of the malfunction indicator lamp is connected to an appropriate terminal on a computer connector 824 that is attached to a vehicular computer 811, the vehicular computer containing a switching device 820 capable of connecting the terminal on the computer connector to a computer ground 823, which is further connected to vehicular ground 822 by means of a different appropriate terminal on computer connector 824.

The vehicular event recorder contains a switching device 836 which connects to a probe wire 834 which, during installation of the vehicular event recorder, is coupled to the terminal on computer connector 824 to which the negative terminal of the malfunction indicator lamp is connected. Vehicular event recorder switching device 836 also connects to vehicular event recorder ground 842 which is further connected to probe wire 832 which, during installation of the vehicular event recorder, is coupled to the terminal on computer connector 824 to which vehicular ground 822 is connected. Thus, the vehicular event recorder is able, by means of switching device 836, to activate the malfunction indicator lamp at such times that vehicular computer 810 is NOT activating the malfunction indicator lamp.

FIG. 14 is a simplified schematic diagram of a second embodiment of the present system which would be utilized in the event that malfunction indicator lamp 818 is controlled by switching the positive supply to the malfunction indicator lamp. Again, only those parts of motor vehicle 810 and vehicular data recorder 812 that are pertinent to one embodiment of the present system are shown. The negative terminal of the malfunction indicator lamp is connected to vehicle ground 822. The positive terminal of the malfunction indicator lamp is connected to an appropriate terminal on computer connector 824 that is attached to vehicular computer 811, the

vehicular computer containing a switching device 820 capable of connecting the terminal on the computer connector to vehicular switched ignition voltage 816 by means of a different appropriate terminal on computer connector 824. Computer ground 823 is connected to vehicular ground 822 by means of an appropriate terminal on the computer connector.

A separate device, an indicator lamp control interface 814, is utilized to allow vehicular event recorder 812 to control the malfunction indicator lamp by means of a positive voltage. The vehicular event recorder contains a switching device 836 which connects to a probe wire 834 which, during installation of the vehicular event recorder, is coupled to a relay coil 838 within indicator lamp control interface 814. The relay coil also connects to probe wire 828 which, during installation of the vehicular event recorder, is coupled to the terminal on computer connector 824 that connects to vehicular switched ignition voltage 816, whereby the vehicular switched ignition voltage is applied to the relay coil. Probe wire 828 also connects the vehicular switched ignition voltage to relay contacts 840 within the indicator lamp control interface, with the other side of the relay contacts connected to probe wire 830 which, during installation of the vehicular event recorder, is coupled to the terminal on computer connector 824 that connects to the positive terminal on malfunction indicator lamp 818.

Vehicular event recorder switching device 836 also connects to vehicular event recorder ground 842, which is further connected to probe wire 832 which, during installation of the vehicular event recorder, is coupled to the terminal on computer connector 824 to which vehicular ground 822 is connected. Thus, the vehicular event recorder is able, by means of switching device 836, to activate relay coil 838 within indicator lamp control interface 814, thereby closing relay contacts 840 to activate the malfunction indicator lamp at such times that vehicular computer 810 is NOT activating the malfunction indicator lamp.

Switching devices 820, 836, and 838/840 can be implemented by means of electro-mechanical relays or by means of any of a variety of solid-state switching devices, including transistors, field-effect-transistors, etc. The functionality of indicator lamp control interface 814 can be implemented in a separate enclosure, as shown in FIG. 14, or can be incorporated into vehicular event recorder 812.

Due to the method employed by most motor vehicles and machine control systems to control a malfunction indicator lamp, in which the malfunction indicator lamp is directly connected to a power source when activated and disconnected from the power source when deactivated, it is possible and practical for an external device to activate the malfunction indicator lamp at such times that the motor vehicle or machine control system is not activating the malfunction indicator lamp, without first disturbing the wiring of the malfunction indicator lamp within the motor vehicle or machine control system. Only by disturbing the wiring of the malfunction indicator lamp, whereby to sever the connection between a control computer and the malfunction indicator lamp, would it be practical for an external device to de-activate the malfunction indicator lamp at such times that the motor vehicle or machine control system is activating the malfunction indicator lamp.

It is not the intent of the present system that the wiring of the malfunction indicator lamp be disturbed, since activation of the malfunction indicator lamp by the control computer within the motor vehicle or machine control system, or steady-state activation of the malfunction indicator lamp by the vehicular event recorder, is an indication to the user of a malfunction requiring the immediate attention of a trained service technician, who will determine and correct the problem.

In order to detect an occurrence of a control computer activating a malfunction indicator lamp that is integral to a motor vehicle or other machine control system, the vehicular event recorder monitors the status of the malfunction indicator lamp at the times that the malfunction indicator lamp is not being activated by the vehicular event recorder. In the circuit of FIG. 13, the voltage level at probe wire 834 can be buffered and coupled to a hardware register, providing a data point whereby the application software in the vehicular event recorder is able to determine the status of the malfunction indicator lamp. In the circuit of FIG. 14, the voltage level at probe wire 830 can be coupled into the vehicular event recorder, buffered, and coupled to a hardware register, providing a data point whereby the application software in the vehicular event recorder is able to determine the status of the malfunction indicator lamp.

FIG. 15 illustrates an embodiment of a universal breakout cable or cabling device for use in connecting a vehicular data recorder to any of the electrical systems

within a motor vehicle. The universal breakout cable comprises a connector 910 that connects to the vehicular data recorder, a group of flexible, insulated wires 912, and metal contact pins 918. A protective jacket 914 is installed on approximately half the length of the flexible insulated wires 192 as protection and to maintain the wires in a contained bundle. The remainder of the length of the flexible insulated wires is left unjacketed, to allow the user to separate the flexible insulated wires 912 as required, in order to reach the desired connection points within the motor vehicle. An insulator 916, such as shrink tubing, is installed to cover the attachment between each individual insulated wire 912 and metal contact pin 918, and to cover part of the length of the metal contact pin. In one embodiment, approximately 1 ¼ inch at the tip of the metal contact pin 918 is left uninsulated.

Metal contact pins 918 can be fashioned from readily available standard #1 sewing needles (shown in FIG. 17). To ensure safety and easy of use, the sharp points on the sewing needles are ground off as shown in FIG. 18. Alternatively, metal contact pins can be custom made with a diameter of 0.040 inches, a length of 2 ½ to 3 inches, a rounded tip as shown in FIG. 18, and an attachment hole similar to the "eye" of a #1 sewing needle. Alternatively, other wire attachment methods including, but not limited to, crimping can be implemented. Other embodiments utilize pins of a different diameter and/or length in order to mate properly with other types of electrical connectors and contacts.

Flexible insulated wires 912 are attached to the metal contact pins by removing the insulation from the ends of the insulated wires, inserting the resulting uninsulated wire into the attachment hole in the metal contact pin and wrapping the uninsulated wire around the metal contact pin as shown in FIG. 19, and applying solder to establish a permanent mechanical and electrical connection.

Insulator 916 provides strain relief for the connection of the flexible insulated wire 912 to the metal contact pin 918. The insulator 916 also prevents shorting of the metal contact pin 918 to nearby conductive objects and provides a convenient surface by which to grasp the metal contact pin during installation and removal of the metal contact pin in a target electronic wiring system. In order to ensure that the insulator will not slide along the length of the metal contact pin during installation and removal of the metal contact pin in the electronic wiring

system, the insulator should be implemented using the type of shrink tubing that is supplied with an adhesive inner liner. In order to provide for ease of installation and removal of the metal contact pin, the insulator should extend ½ to ¾ inch along the length of the flexible insulated wire. The insulator 916 on each of the metal pins 918 may be permanently marked with an easily recognizable identifier to indicate either a) the target system signal to which the metal contact pin should be connected or b) the input on the data recorder to which the metal contact pin is attached. The identifier may be protected from abrasion by installing an additional, transparent insulator over the identifier. Ease of use may also be enhanced by attaching or fixing a duplicate of the identifier on the flexible insulated wire at a location on the flexible insulated wire that is close to protective jacket 914.

The present system will be utilized by selecting the appropriate terminal on the appropriate vehicular connector, and then inserting the corresponding metal contact pin 918 alongside the vehicular wire attached to the terminal and into the body of the vehicular connector, through any existing integral rubber seal, such that the uninsulated section of the metal contact pin 918 is inserted between the plastic connector housing and the metal terminal to which the vehicular wire is attached.

Due to the design of modern motor vehicle connectors and the design of the metal contact pins 918 of the present system, when the metal contact pin is inserted through the integral rubber seal and between the plastic connector housing and the vehicular wire terminal, sufficient pressure will be exerted between the vehicular wire terminal and the metal contact pin so as to ensure a good electrical connection, and so as to provide sufficient friction to retain the metal contact pin within the plastic connector housing and in contact with the vehicular wire terminal until such time as the metal contact pin is intentionally removed from the plastic connector housing.

FIG. 16 illustrates a second embodiment of a universal breakout cable that further consists of a multi-pin in-line connector 922, which connects by means of a short, flexible, multi-conductor cable 920 to the connector 910 which mates with the data recorder. The in-line connector 922 provides an interface to an appropriate and desired electronic sensor, including but not limited to a pressure sensor for the purpose of monitoring vehicular fuel pressure, by means of a sensor cable.

FIG. 21 is a schematic diagram illustrating the design of one embodiment of a sensor cable, which consists of an appropriate multi-pin in-line connector 1032 for mating with in-line connector 922, whereby the in-line connector 922 provides power and ground to an attached sensor, through connecting wires 1034 and an appropriate sensor connector 1030, while also providing a path to connect the sensor output to a desired input to the data recorder. Connector 1032 contains a built-in wire jumper 1024 that acts to connect a digital input on the data recorder to ground, indicating that a sensor is actually present.

FIG. 22 is a schematic diagram illustrating the design of an optional and alternative "auxiliary data probe", constructed without the built-in jumper, that can be connected to in-line connector 922 when an electronic sensor is not in use. The auxiliary data probe consists of a flexible, insulated wire 1034 (similar to 912), a probe pin 1036 (similar to metal contact pin 918), and an insulator (similar to 916), with the insulated wire, metal contact pin, and insulator attached to an appropriate multi-pin in-line connector 1032 to mate with the in-line connector 922. The auxiliary data probe can be connected to a signal of the user's choice.

FIG. 20 is a schematic diagram illustrating the basic concept of a custom breakout cable for use in connecting a vehicular data recorder to specific electrical signals within a specific group of motor vehicles. The custom breakout cable comprises one or more Breakout Cable connector plug(s) 1012 that connect to one or more computer connector(s) 1004 in place of corresponding vehicle wiring harness connector(s) 1006 within a motor vehicle, one or more Breakout Cable jack(s) 1010 to which the corresponding vehicle wiring harness connector(s) are connected, a group of feedthrough wires 1014, one or more add-on instrument connector(s) 1018 which connect to the vehicular data recorder, a group of probe wires 1016 which couple the add-on instrument connector(s) to the Breakout Cable connector plug(s), one or more auxiliary connector(s) 1022, and one or more group(s) of auxiliary interconnect wires 1026 which couple the auxiliary connector(s) to the add-on instrument connector(s).

Electrical signals by which a vehicle on-board computer 1000 controls actuators and receives data from sensors within a vehicle control system 1002 are normally coupled through the computer connector(s) 1004 and attached mating

vehicle harness connector(s) 1006. The current system is implemented by removing the mating vehicle harness connector(s) from the computer connector(s) 1004, attaching the appropriate Breakout Cable connector plug(s) 1012 to the computer connector(s), and attaching the mating vehicle harness connector(s) to the appropriate Breakout Cable connector jack(s). The coupling of all electrical signals between the computer connector(s) 1004 and attached mating vehicle harness connector(s) 1006 is accomplished by the feedthrough wires connecting the corresponding terminals on the Breakout Cable connector plug(s) and the Breakout Cable connector jack(s), so that vehicle operation is unimpeded. Probe wires 1016 are attached to the feedthrough wires 1014 that couple to electrical signals of interest, with the probe wires attaching to appropriate terminals on one or more add-on instrument connector(s) 1018, such that the electrical signals of interest are coupled to the vehicular data recorder. Multiple add-on instrument connectors allow for flexibility in the use of the current system; for example, engine-related signals can be coupled to one connector while transmission-related signals are coupled to a second connector. Where appropriate, an electrical signal coupled through an individual feedthrough wire 1014 can be coupled to more than one of the add-on instrument connectors (some examples are: battery voltage, ground, switched ignition).

One or more appropriate and desired electronic sensors, including but not limited to pressure sensors for the purpose of monitoring vehicular fuel pressure or vehicular transmission pressures, can be coupled to add-on instrument connector 1018 by means of one or more auxiliary connector(s) 1022 and appropriate auxiliary interconnect wires 1026.

A first embodiment of a custom breakout cable of the present system, for use in connecting a vehicular data recorder to late-model OBDII-equipped General Motors (GM) automobiles, will be described in conjunction with FIG. 23 through FIG. 27. FIG. 23 depicts a method of attaching flexible, insulated wires 912 to a GM OBDII header 930 (which is constructed with 160 pin-type contacts) which has been assembled with special straight pins rather than the standard right-angle pins with which the OBD II header is customarily supplied to General Motors for use in vehicular computers.

The flexible, insulated wires are installed into two (2) GM OBDII cable connectors 932 (which are each constructed with 80 socket-type contacts, such that two of these connectors are required). Wires that are designated as feed-through wires (1014 on FIG. 20) are routed away from the GM OBDII cable connectors 932 in one direction, while wires that are designated as probe wires (1016 on FIG. 20) are routed away in the other direction. Note that all contacts in the GM OBDII cable connectors 932 contain a wire 912 that is designated as a feed-through wire, and that more than one wire 912 is installed in any contact containing a wire 912 that is designated as a probe wire. Subsequent to the installation of the flexible, insulated wires into the cable connectors 932, the cable connectors are plugged onto the back of the GM OBDII header as shown in FIG. 24. FIG. 25 depicts the connector assembly of FIG. 24 with the addition of protective jackets 914 on the bundles of wires that are now attached to the connector assembly. FIG. 26 depicts the connector assembly of FIG. 25 enclosed within a protective covering, which can consist of a sheet metal box, plastic box, or epoxy encapsulant 934.

FIG. 27 illustrates a completed embodiment of a custom Breakout Cable according to aspects of the present system. The flexible, insulated wires 912 and protective jackets 914 incorporated in a connector assembly as depicted in FIG. 26 are of sufficient length so as to extend approximately 18 inches from the GM OBDII header 930 and sheet metal box, plastic box, or epoxy encapsulant 934. The flexible, insulated wires which are designated as feed-through wires (1014 on FIG. 20) are coupled to GM OBDII cable connectors 932 in a one-to-one correspondence that provides a connection from pin 1 on header 930 to pin 1 on cable connector 932, a connection from pin 2 on the header to pin 2 on the cable connector, etc.

The flexible, insulated wires which are designated as probe wires (1016 on FIG. 20) are coupled to two separate connectors 910 that individually connect to the vehicular data recorder. As detailed above, each of the connectors 910 can attach to shared and to unique electrical signals present at GM OBDII header 932, in order that different vehicular activity may be recorded by the vehicular data recorder. One connector 910 further attaches by means of a short, flexible, multi-conductor cable 920 to a multi-pin in-line connector 922, whereby an appropriate and desired electronic sensor may be connected to the vehicular data recorder.

FIG. 28 illustrates a second embodiment of a custom breakout cable of the present system, similar to the first embodiment, wherein both vehicular data recorder connectors 910 are coupled to multi-pin in-line connectors 922, allowing for additional use of appropriate and desired add-on electronic sensors. As desired, additional multi-pin in-line connectors 922 can be added, allowing the use of additional add-on electronic sensors, when the add-on electronic device to which connector 910 attaches is configured to facilitate the use of the additional add-on electronic sensors.

A third embodiment of a custom breakout cable of the present system, also for use in connecting a vehicular data recorder to late-model OBDII-equipped General Motors (GM) automobiles, will be described in conjunction with FIG. 29 through FIG. 34. FIG. 29 depicts a custom manufactured male/female metal contact 936, consisting of a pin at one end and a socket at the other end, wherein the pin and socket are dimensionally similar to the pins and sockets employed in the OBDII connectors that are used in the OBDII-equipped automobiles. The custom manufactured male/female metal contact is formed with a through-hole located near its center, providing a means whereby a flexible insulated wire 912 may be attached to the male/female metal contact, typically by means of solder.

FIG. 30 depicts two (2) views of a custom plastic connector housing 938, with a cutaway view depicting a group of male/female metal contacts 936 installed. The plastic connector housing is constructed such that the side which houses the socket side of male/female metal contact 936 will effectively mate with a GM OBDII header 930 that is integral to an automotive computer, whereas the side which houses the pin side of the male/female contact will effectively mate with a GM OBDII cable connector 932 that is integral to an automotive wiring harness. As illustrated in FIG. 30, custom plastic connector housing 938 is designed such that a raised channel 940 is provided on each side of the connector housing, for the purpose of allowing the installation of probe wires within the plastic connector housing.

FIG. 31 is a cutaway view of plastic connector housing 938 which depicts the installation of flexible insulated wires 912 into several male/female metal contacts 936, to serve as probe wires connecting targeted electrical signals within the plastic

connector housing to the vehicular data recorder. FIG. 32 depicts an assembled breakout connector 942, comprising custom plastic connector housing 938, installed male/female metal contacts 936, and installed flexible insulated wires 912 which exit raised channel 940 at one end of the plastic connector housing. Alternative designs would provide for the flexible insulated wires to exit the raised channel at both ends of the plastic connector housing, or at another point along the length of the raised channel. FIG. 33 depicts a side view of the assembled breakout connector 942 with flexible insulated wires 912 exiting from raised channels 940 on both sides of the breakout connector. An alternative design could provide for a raised channel 940 on only one side of custom plastic connector housing 938, in the event that this would improve ease-of-use.

FIG. 34 illustrates a completed third embodiment of a custom Breakout Cable according to the present system, which is functionally equivalent to the second embodiment illustrated in FIG. 28. The third embodiment utilizes custom breakout connectors 942 in place of the GM OBDII header 930, the GM OBDII cable connectors 932, and the flexible insulated feed-through wires 912 connecting the header 930 and the cable connectors 932 in the second embodiment.

In accordance with principles of the present system, there are numerous other techniques that can be employed in fabricating custom breakout connectors and cable assemblies, which are applicable to virtually any and all connector systems employed in motor vehicles and other types of machine control systems. One such technique will be described in conjunction with FIG. 35 through FIG. 38. FIG. 35 depicts a set of typical automotive mating connectors. A cable connector 946, which contains socket-type contacts intended for attachment to the individual wires within a motor vehicle wiring harness, is designed to mate with a computer header 944, which contains right-angle pin-type contacts and is intended for attachment to a pc board within a motor vehicle computer. Matching sets of the cable connectors and the computer headers can be wired together as illustrated in FIG. 36, using short lengths of flexible insulated wire 912, with socket #1 of the cable connector attached to pin #1 of the computer header, socket #2 of the cable connector attached to pin #2 of the computer header, etc., to form a feed-through connector which can be installed between a vehicular cable connector and its mating header on the vehicular

computer. FIG. 37 illustrates the attachment of additional flexible insulated wires 912 to desired header contacts, to serve as probe wires connecting the corresponding electrical signals on the header contacts to a vehicular data recorder, thus forming a custom breakout connector. FIG. 38 depicts the connector assembly of FIG. 37 enclosed within a protective covering, which can consist of a sheet metal box, plastic box, or epoxy encapsulant 934.

Another technique will be described in conjunction with FIG. 39 through FIG. 41. FIG. 39 depicts a set of right-angle socket contacts 950, designed to mate with the pin contacts in computer header 944, and used to convert cable connector 946 into a right-angle pc mounted connector. FIG. 40 illustrates the right-angle socket contacts installed in the cable connector, with the combination thereof attached to a printed circuit board 952. Computer header 944 is also attached to the printed circuit board, with copper traces on the printed circuit board acting to connect pin #1 of the computer header to socket #1 of the cable connector and pin #2 of the computer header to socket #2 of the cable connector, etc., to form a feed-through connector which can be installed between a vehicular cable connector and its mating header on the vehicular computer.

Flexible insulated wires 912 are further attached to the printed circuit board, in such a way as to be in contact with the copper traces that are connected to desired contacts on the computer header, to serve as probe wires connecting the corresponding electrical signals on the header contacts to a vehicular data recorder, thus forming a custom breakout connector. FIG. 41 depicts the connector assembly of FIG. 40 enclosed within a protective covering, which can consist of a sheet metal box, plastic box, or epoxy encapsulant 934.

Breakout connectors constructed using these and other techniques can be incorporated into breakout cable systems similar to that illustrated in FIG. 34, thereby producing custom breakout cables for any desired motor vehicle or machine control system. In alternative embodiments, the breakout cable systems described above can be used with other accessories. In addition to being a feed-through device as described above, an active device which changes one of the data signals can be used with the breakout cable systems described above. For example, the breakout

cable system can be used to connect an automotive vehicle theft alarm or car-starter device to the electronics of the vehicle.

The present system is not limited to short-duration data recording such as is appropriate for pinpointing intermittent failures, but may be employed for longer term data recording and analysis. For example, some jurisdictions within the United States have implemented motor vehicle inspection programs in which the vehicle is put through a driving regimen which simulates a variety of driving conditions. In the event that the vehicle emissions exceed permitted levels during the course of the test sequence, trained service technicians must diagnose and correct the cause of the failure. An embodiment of the present system could be optimized for single-event, longer term recording, so as to provide a record of the entire driving test. This record could then be extracted and displayed, allowing a trained service technician to observe all pertinent system activity as it occurred during the test sequence, providing a valuable tool in diagnosing the cause of a failure.

An embodiment of the present system could be adapted for use in boats and ships, for use in monitoring and recording electrical signal activity within any computerized control system which is experiencing intermittent anomalies. In addition to the computerized control of engine operation, boats and ships typically contain computerized navigation systems. The computerized navigation systems comprise multiple sensors and actuators and are subject to the same types of intermittent anomalies as other computer-controlled machine systems. As in motor vehicles, the present system will facilitate the timely and accurate identification of sources of intermittent anomalies within any of the electrical systems comprising a boat or ship.

An embodiment of the present system could be adapted for use in monitoring and recording electrical signal activity within an aircraft that is experiencing intermittent anomalies. A key and complex computerized system within a modern aircraft is the "auto-pilot", which frequently controls many of the routine maneuvers and steady-state flight functions of the aircraft. The auto-pilot system is subject to the same types of intermittent anomalies as other computer-controlled machine systems, anomalies which can cause sudden and severe altitude changes, banking maneuvers, and other unexpected aircraft movement that can be

unnerving and life-threatening. Complicating efforts to identify the source of an intermittent anomaly within an aircraft is the fact that key electronic systems are frequently located in parts of the aircraft that are inaccessible during flight (e.g., in the tail section). Identification and repair of intermittent anomalies within aircraft electronic systems has typically been accomplished in much the same manner that has been employed in motor vehicles, which consists of replacing system components until the problem ceases to occur. The present system facilitates timely and accurate identification of the sources of intermittent anomalies within aircraft electrical systems, thus contributing to increased comfort and safety of air travel and reduced aircraft maintenance costs.

The present system is not limited to use as a data recording device, but may be employed as part of a real-time or quasi real-time monitor and display device, similar in function to a multi-channel oscilloscope. The digital data that is generated by the analog-to-digital conversion process can be transferred through the high-speed communications port 138 to an external computer 150 for immediate display, rather than transferred to a data storage subsystem 136. This would allow the user to observe system activity as it occurs rather than at a later time, providing another valuable tool to the service technician, especially as a means to verify that reliable connection to desired signals has been achieved and that the correct signals are being probed when using wire-piercing probes or a universal breakout cable. In the event that a market need is identified, a further embodiment of the present system could be adapted to transfer the digital data simultaneously to the high-speed communications port and to the data storage subsystem, providing a means to store the system activity as it is presented for real-time viewing on the external computer.

The present system is not limited to use in motor vehicles, ships, aircraft, and photocopiers, but may be employed to monitor and record electrical signal activity in other types of computerized machine control systems. For example, modern HVAC systems, which contain one or more control computers with associated sensors and actuators, frequently experience short-term intermittent failures which are difficult to identify and correct. With appropriate signal probes and / or feed-through connectors, the present system can be deployed to monitor and record electrical activity within HVAC control systems and within other computerized

equipment and machinery. Appropriate trigger events could be determined and implemented, as well as a user trigger device and visual indicator(s) appropriate to the particular application.

As the foregoing discussion demonstrates, numerous modifications, substitutions and equivalents will now occur to those skilled in the art, all of which fall within the spirit and scope contemplated by the present system.

CLAIMS

1. A system for diagnosing failures in a computer-controlled machine, the machine having a controller and an event node, with an interconnect system disposed between the controller and the event node for exchanging event data, the system comprising:

    an event data recorder coupled to the interconnect system for selectively storing event data.

2. The system of claim 1, wherein the event data recorder stores event data of the machine for later analysis.

3. The system of claim 1, wherein the event node includes at least one actuator, sensor, or indicator.

4. The system of claim 1, wherein the machine is an automotive vehicle.

5. The system of claim 4, wherein:

    the event data recorder stores data generated by a component of the automotive vehicle; and

    the event data recorder is directly connected to the event node.

6. The system of claim 4, wherein the event data recorder stores event data which is not monitored by the controller.

7. The system of claim 4, wherein the event data recorder is triggered to store the event data by a user input.

8. The system of claim 7, wherein the user actuates an actuator to initiate storing of the event data.

9. The system of claim 8, wherein the actuator is mounted within reach of an operator of the vehicle.

10. The system of claim 8, wherein the actuator is coupled to a wire-less transmitter that communicates with the event data recorder.

11. The system of claim 1, wherein the event data recorder includes an onboard power source.

12. The system of claim 4, wherein the event data recorder is triggered to store the event data by a stall of an engine of the vehicle.

13. The system of claim 4, wherein the event data recorder is triggered to store the event data by a shut-down of a vehicular control system.

14. The system of claim 4, wherein the event data recorder is triggered to store the event data by an alarm indication.

15. The system of claim 1, further comprising a feedback system to provide information to a user of the event data recorder.

16. The system of claim 15, wherein the provided information indicates that the event data recorder is storing the event data.

17. The system of claim 15, wherein the provided information is conveyed by an indicator lamp of the machine.

18. The system of claim 15, wherein the provided information indicates an operating state of the event recorder.

19. The system of claim 1, wherein the event data recorder includes at least one circuit board shock-mounted to a housing of the event data recorder.

20. The system of claim 1, further comprising a cabling device that connects the event data recorder to at least one electrical system of the machine.

21. The system of claim 20, wherein the cabling device connects to the electrical system without damaging any existing electrical wiring.

22. The system of claim 21, wherein the cabling device includes a plurality of contact pins connected to a plurality of wires for inserting into electrical connection points of the machine.

23. The system of claim 20, wherein the cabling device includes a multi-pin in-line connector to provide an interface to an electronic sensor of the machine.

24. The system of claim 23, wherein the sensor is a temporarily installed sensor.

25. The system of claim 20, wherein the cabling device is particularly adapted for the machine.

26. The system of claim 25, wherein the cabling device comprises:

at least one connector plug that connects to a computer of the machine;

at least one cable jack that connects to at least one actuator or sensor of the machine;

a plurality of feedthrough wires that connect the connector plug and cable jack; and

at least one instrument connector that connects at least one the feedthrough wires to the event data recorder.

27. The system of claim 26, further comprising an auxiliary connector that connects to the instrument connector.

28. The system of claim 1, further comprising a display device able to be coupled to the event data recorder to access the event data stored in the event data recorder.

29. A system for use with an automotive vehicle to facilitate determining the cause of an intermittent failure, comprising:

a processor that controls operation of an event data recorder;

a recording device that receives real time event data from the vehicle and stores the same for later analysis; and

a wire-less transmitter including an actuator that, when actuated by a user, initiates storing of the event data.

30. The system of claim 29, wherein the recording device stores a predetermined amount of real-time data upon initiation of the event data recorder.

31. The system of claim 29, wherein the recording device stores the contents of a continuous loop of event data.

32. The system of claim 29, wherein the event data recorder includes a power source such that the event data recorder can function without any external power.

33. The system of claim 29, wherein the event data recorder is triggered to store the event data by a stall of an engine of the vehicle.

34. The system of claim 29, wherein the event data recorder is triggered to store the event data by a shut-down of a vehicular control system.

35. The system of claim 29, wherein the event data recorder is triggered to store the event data by an alarm indication.

36. The system of claim 29, further comprising a feedback system to provide information to a user of the event data recorder.

37. The system of claim 36, wherein the provided information indicates that the event data recorder is storing the event data.

38. The system of claim 36, wherein the provided information is conveyed by an indicator lamp of the machine.

39. The system of claim 36, wherein the provided information indicates an operating state of the event recorder.

40. The system of claim 29, wherein the event data recorder includes at least one circuit board shock-mounted to a housing of the event data recorder.

41. The system of claim 29, further comprising a cabling device that connects the event data recorder to at least one electrical system of the machine.

42. The system of claim 41, wherein the cabling device connects to the electrical system without damaging any existing electrical wiring.

43. The system of claim 42, wherein the cabling device includes a plurality of contact pins connected to a plurality of wires for inserting into electrical connection points of the machine.

44. The system of claim 41, wherein the cabling device includes a multi-pin in-line connector to provide an interface to an electronic sensor of the machine.

45. The system of claim 44, wherein the sensor is a temporarily installed sensor.

46. The system of claim 41, wherein the cabling device is particularly adapted for the machine.

47. The system of claim 46, wherein the cabling device comprises:

at least one connector plug that connects to a computer of the machine;

at least one cable jack that connects to at least one actuator or sensor of the machine;

a plurality of feedthrough wires that connect the connector plug and cable jack; and

at least one instrument connector that connects at least one the feedthrough wires to the event data recorder.

48. The system of claim 47, further comprising an auxiliary connector that connects to the instrument connector.

49. The system of claim 29, further comprising a display device able to be coupled to the event data recorder to access the event data stored in the event data recorder.

50. A method for diagnosing failures in a computer-controlled machine, the machine having a controller and an event node, with an interconnect system disposed between the controller and the event node for exchanging event data, the method comprising:

coupling an event data recorder to the interconnect system; and

storing real time data from the machine.

51. The method of claim 50, further comprising storing the event data of an automotive vehicle for later analysis.

52. The method of claim 50, wherein the event node includes at least one actuator, sensor, or indicator, further comprising connecting the event data recorder directly to the event node.

53. The method of claim 50, further comprising triggering the event data recorder to store the event data by a user input.

54. The method of claim 53, further comprising triggering the event data recorder with a wire-less transmitter that communicates with the event data recorder.

55. The method of claim 53, further comprising indicating to the user when the event data recorder is storing the data.

56. The method of claim 50, further comprising triggering the event data recorder to store the data by a stall of an engine of the vehicle.

57. The method of claim 50, further comprising triggering the event data recorder to store the data by an alarm indication

58. The method of claim 50, further comprising shock-mounting at least one circuit board to a housing of the event data recorder.

59. The method of claim 50, further comprising alerting the user that the event data recorder is installed and working properly.

60. The method of claim 50, further comprising connecting the event data recorder to the interconnect system without damaging any existing electrical wiring.

61. The method of claim 60, further comprising inserting a plurality of contact pins connected to a plurality of wires into electrical connection points of the machine.

62. The method of claim 60, further comprising including a multi-pin in-line connector to provide an interface to an electronic sensor of the machine.

63. The method of claim 57, further comprising visually displaying the stored data.

64. A method for conveying information from a device not an original equipment device connected to a machine, comprising flashing an indicator lamp of the machine in predetermined patterns under the control of the device.

65. The method of claim 64, wherein the pattern indicates the device is installed properly.

66. The method of claim 64, wherein the pattern indicates the device is performing a commanded function.

67. A system for conveying information from a device not an original equipment device connected to a machine, comprising an electronic circuit that flashes an indicator lamp of the machine in predetermined patterns under the control of the device.

68. The system of claim 67, wherein the pattern indicates the device is installed properly.

69. The system of claim 67, wherein the pattern indicates the device is performing a commanded function.

70. A system for testing a computer-controlled machine, comprising:
a testing device coupled to an electrical system of the machine; and
a wireless device that controls at least one function of the testing device.

71. The system of claim 70, wherein the machine is a motor vehicle and the wireless device is mounted within reach of the driver of the vehicle.

72. The system of claim 71, wherein the wireless device is mounted on a steering mechanism.

73. A method of testing a computer-controlled machine, comprising:
connecting a testing device to an electrical system of the machine; and
controlling at least one function of the testing device with a wireless device.

74. The method of claim 73, wherein the machine is a motor vehicle, further comprising mounting the wireless device within reach of a driver of the vehicle.

75. The method of claim 74, further comprising mounting the wireless device on a steering mechanism.

76. A cabling device for connecting an accessory to a machine, comprising a plurality of contact pins connected to a plurality of wires for inserting into electrical connection points of the machine.

77. The cabling device of claim 76, wherein the accessory is an automotive car-starter device.

78. The cabling device of claim 76, wherein the accessory is an automotive vehicle theft alarm.

79. A method for connecting an accessory to a machine, comprising inserting a plurality of contact pins connected to a plurality of wires into electrical connection points of the machine.

80. The method of claim 79, further comprising connecting an automotive car-starter device to the machine.

81. The method of claim 79, further comprising connecting an automotive vehicle theft alarm to the machine.

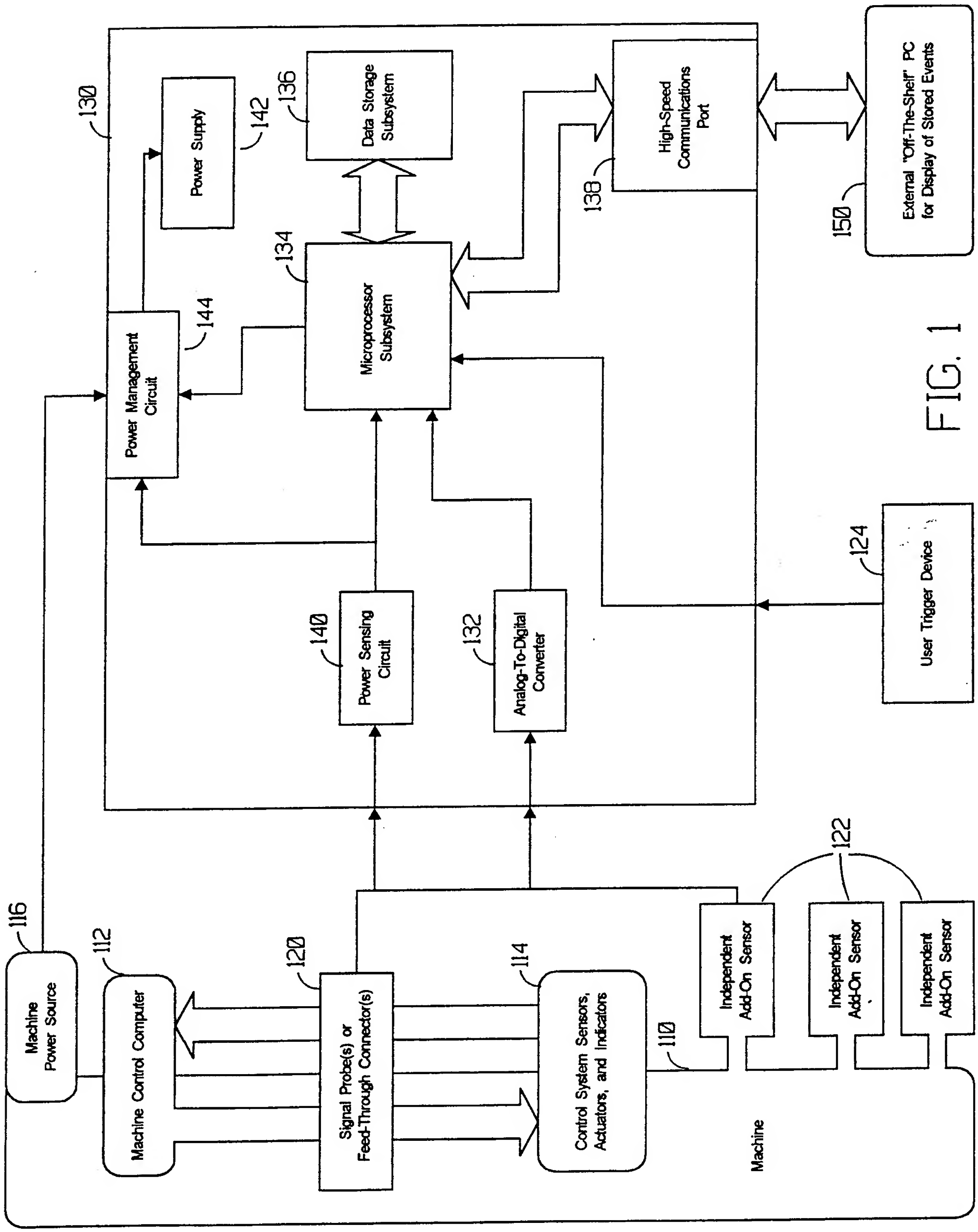

130
Power Supply
142
Data Storage Subsystem
136
High-Speed Communications Port
138
External "Off-The-Shelf" PC for Display of Stored Events
150
Microprocessor Subsystem
134
Power Management Circuit
144
Power Sensing Circuit
140
Analog-To-Digital Converter
132
User Trigger Device
124
122
Machine Power Source
116
Machine Control Computer
112
Signal Probe(s) or Feed-Through Connector(s)
120
Control System Sensors, Actuators, and Indicators
114
110
Independent Add-On Sensor
Independent Add-On Sensor
Independent Add-On Sensor
Machine

FIG. 1

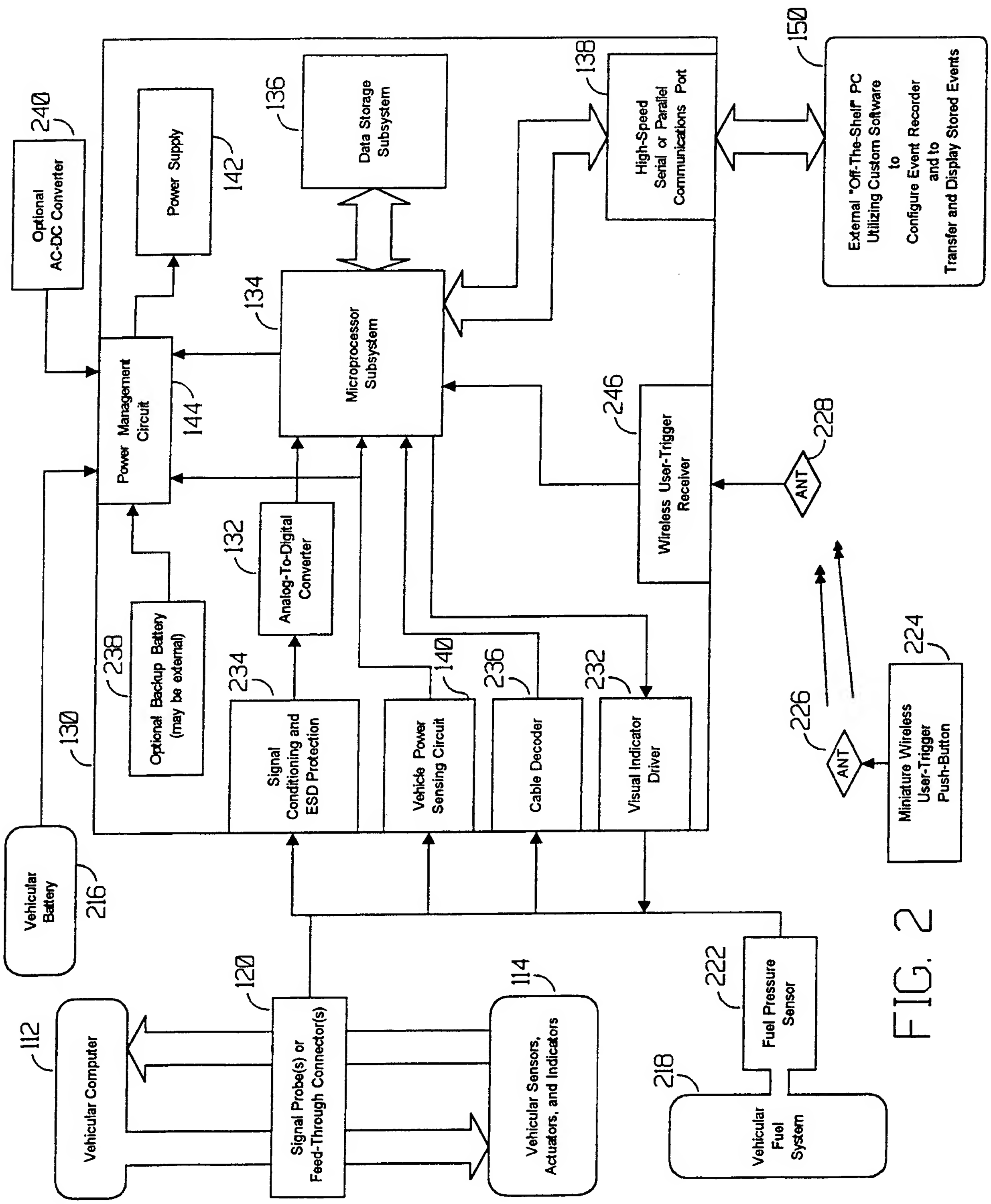

Optional AC-DC Converter
240
Power Supply
142
Data Storage Subsystem
136
138
High-Speed Serial or Parallel Communications Port
150
External "Off-The-Shelf" PC Utilizing Custom Software to Configure Event Recorder and to Transfer and Display Stored Events
134
Microprocessor Subsystem
Power Management Circuit
144
246
Wireless User-Trigger Receiver
ANT
228
Analog-To-Digital Converter
132
Optional Backup Battery (may be external)
238
234
Signal Conditioning and ESD Protection
140
Vehicle Power Sensing Circuit
236
Cable Decoder
232
Visual Indicator Driver
130
226
ANT
Miniature Wireless User-Trigger Push-Button
224
Vehicular Battery
216
120
Signal Probe(s) or Feed-Through Connector(s)
112
Vehicular Computer
114
Vehicular Sensors, Actuators, and Indicators
222
Fuel Pressure Sensor
218
Vehicular Fuel System

FIG. 2

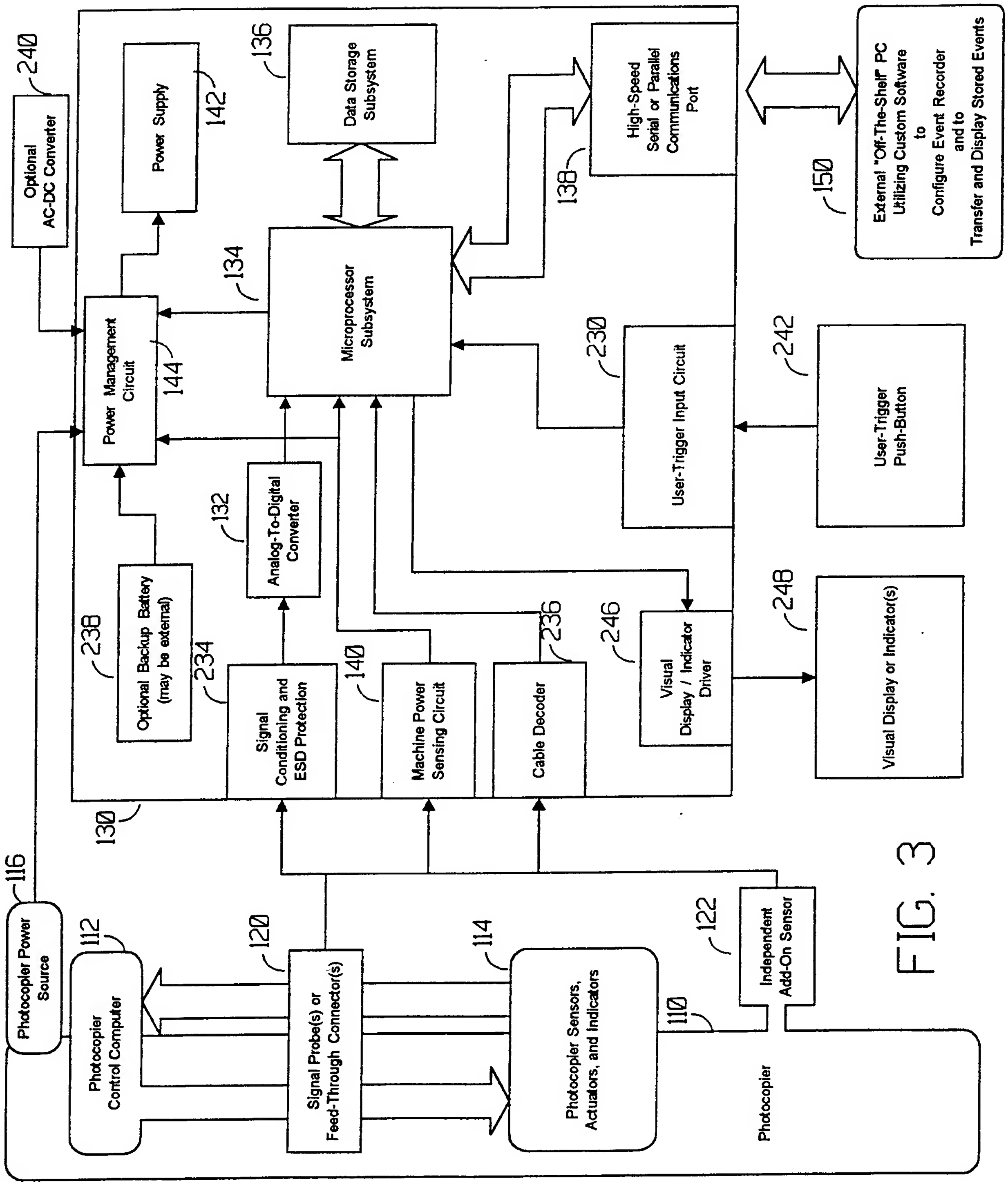
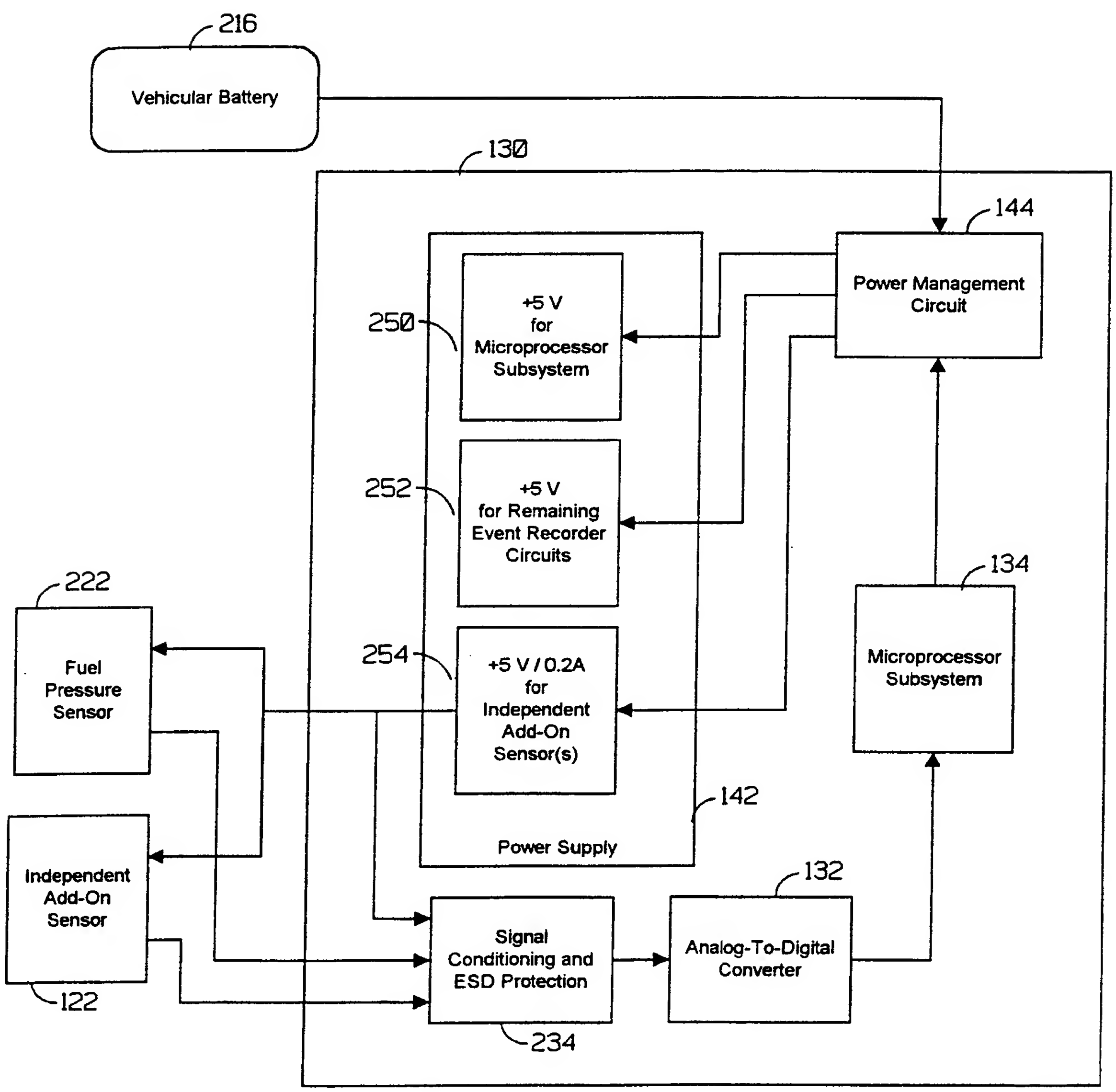

Optional AC-DC Converter
240
Power Supply
142
Data Storage Subsystem
136
High-Speed Serial or Parallel Communications Port
138
External "Off-The-Shelf" PC Utilizing Custom Software to Configure Event Recorder and to Transfer and Display Stored Events
150
Power Management Circuit
144
Microprocessor Subsystem
134
User-Trigger Input Circuit
230
User-Trigger Push-Button
242
Analog-To-Digital Converter
132
Optional Backup Battery (may be external)
238
Signal Conditioning and ESD Protection
234
Machine Power Sensing Circuit
140
Cable Decoder
236
Visual Display / Indicator Driver
246
Visual Display or Indicator(s)
248
130
Photocopier Power Source
116
Photocopier Control Computer
112
Signal Probe(s) or Feed-Through Connector(s)
120
Photocopier Sensors, Actuators, and Indicators
114
Independent Add-On Sensor
122
110
Photocopier

FIG. 3

FIG. 4



216
Vehicular Battery
130
144
Power Management Circuit
250
+5 V for Microprocessor Subsystem
252
+5 V for Remaining Event Recorder Circuits
254
+5 V / 0.2A for Independent Add-On Sensor(s)
142
Power Supply
134
Microprocessor Subsystem
222
Fuel Pressure Sensor
Independent Add-On Sensor
122
Signal Conditioning and ESD Protection
234
132
Analog-To-Digital Converter

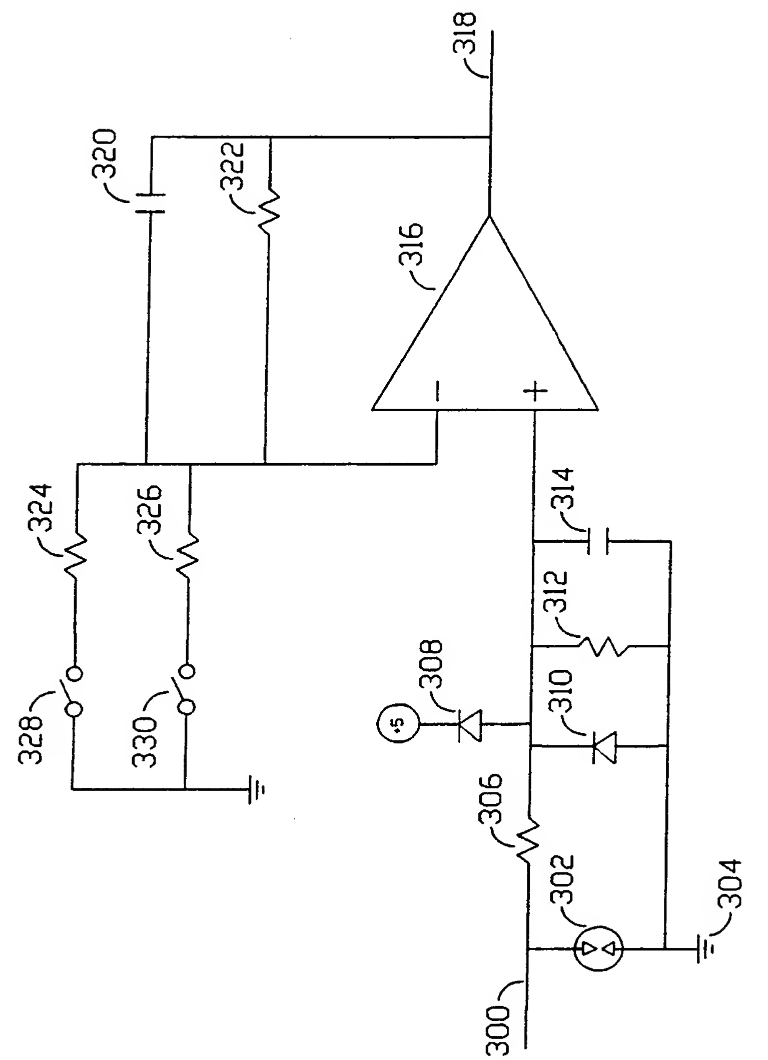


FIG. 5

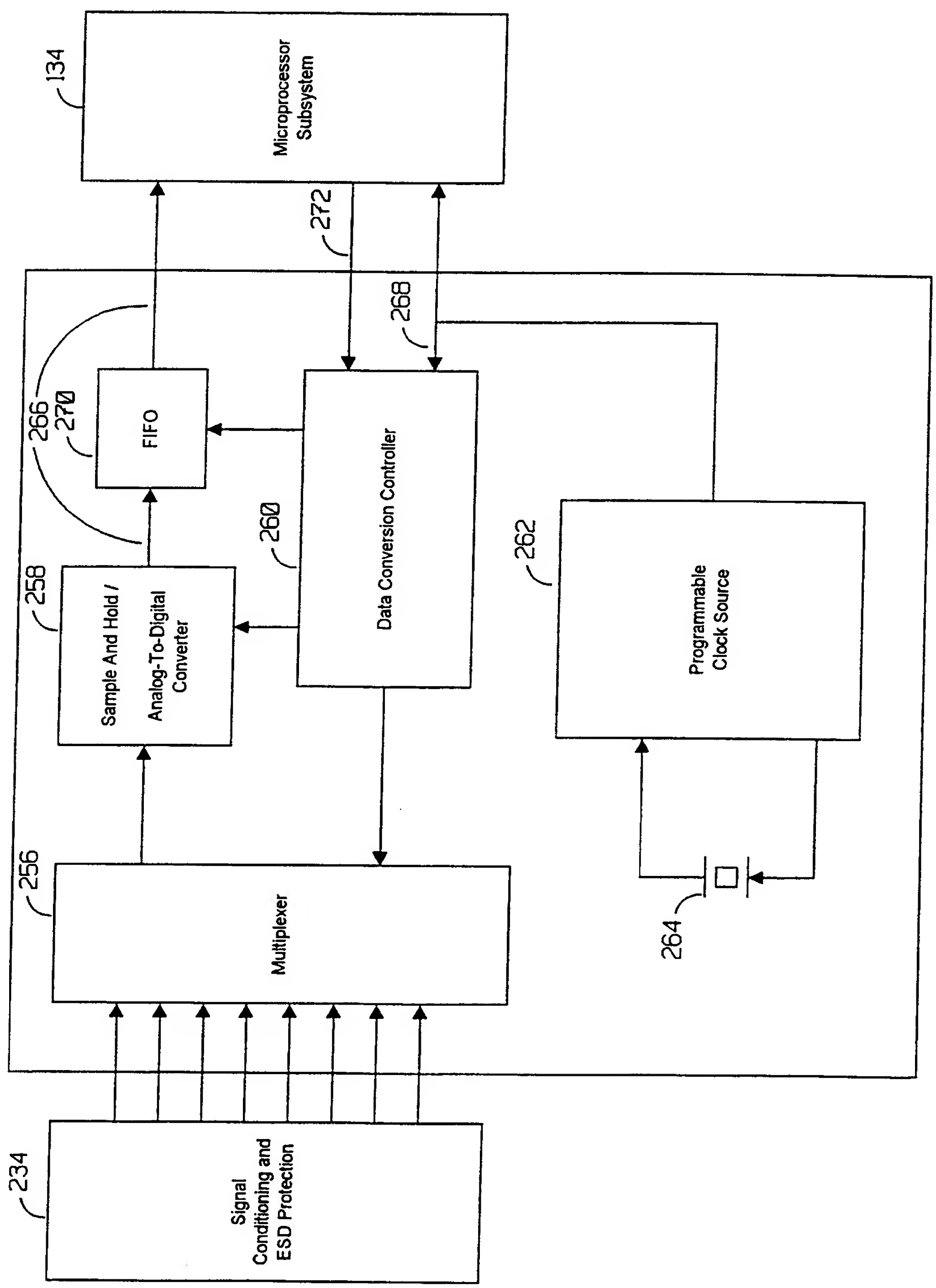

134
Microprocessor Subsystem
272
268
266
270
FIFO
Data Conversion Controller
260
262
Programmable Clock Source
258
Sample And Hold / Analog-To-Digital Converter
256
Multiplexer
264
234
Signal Conditioning and ESD Protection

FIG. 6

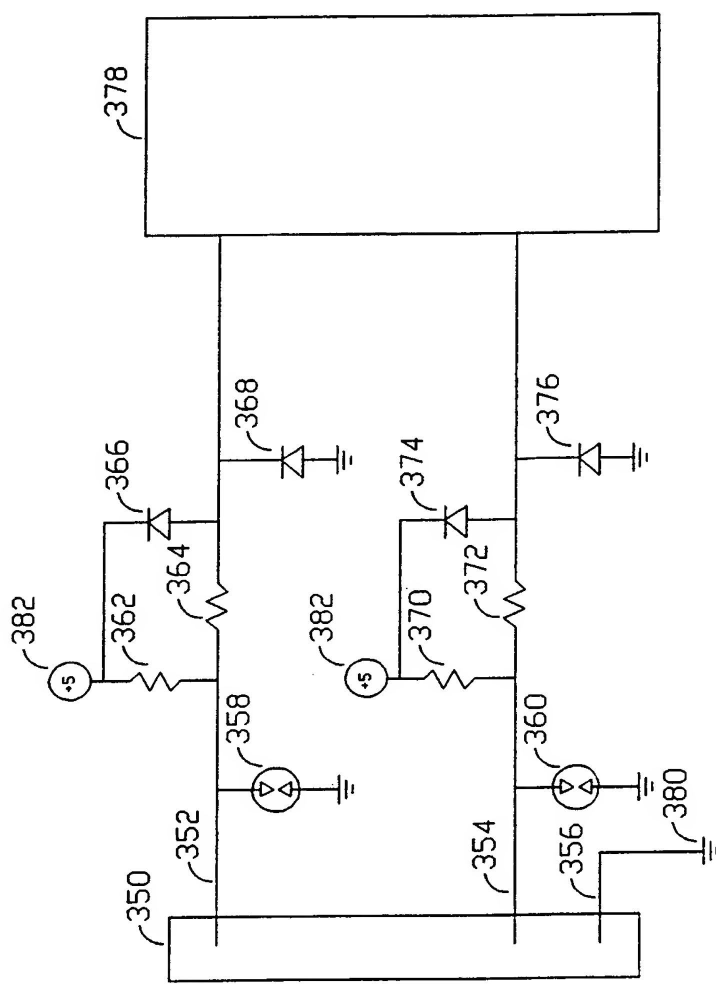

378
366
368
374
376
382
362
364
382
370
372
358
360
352
354
356
380
350
+5
+5

FIG. 7

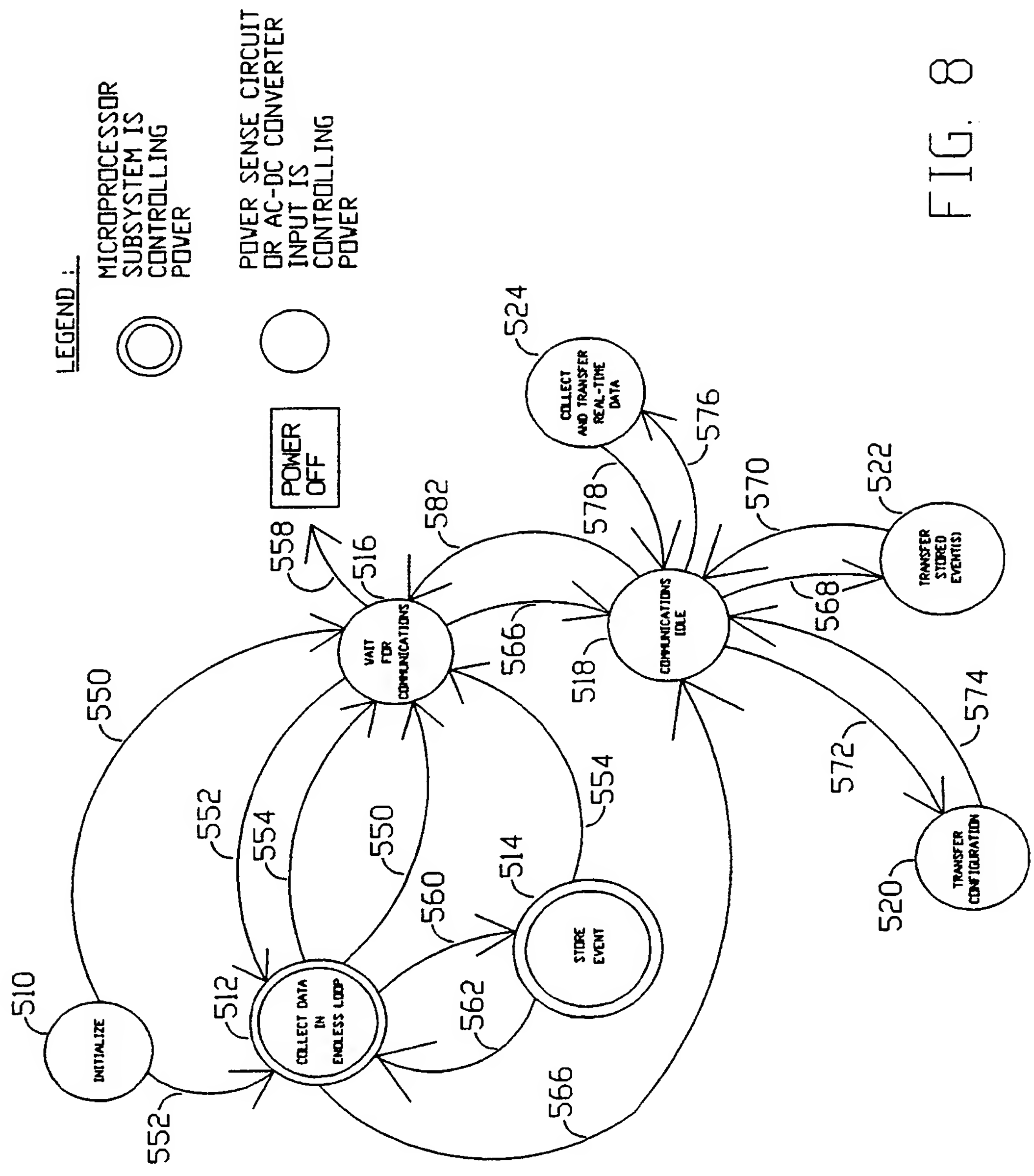

LEGEND :
MICROPROCESSOR SUBSYSTEM IS CONTROLLING POWER
POWER SENSE CIRCUIT OR AC-DC CONVERTER INPUT IS CONTROLLING POWER
POWER OFF
INITIALIZE
COLLECT DATA IN ENDLESS LOOP
STORE EVENT
WAIT FOR COMMUNICATIONS
COMMUNICATIONS IDLE
COLLECT AND TRANSFER REAL-TIME DATA
TRANSFER STORED EVENT(S)
TRANSFER CONFIGURATION
510
512
514
516
518
520
522
524
550
552
554
558
560
562
566
568
570
572
574
576
578
582

FIG. 8

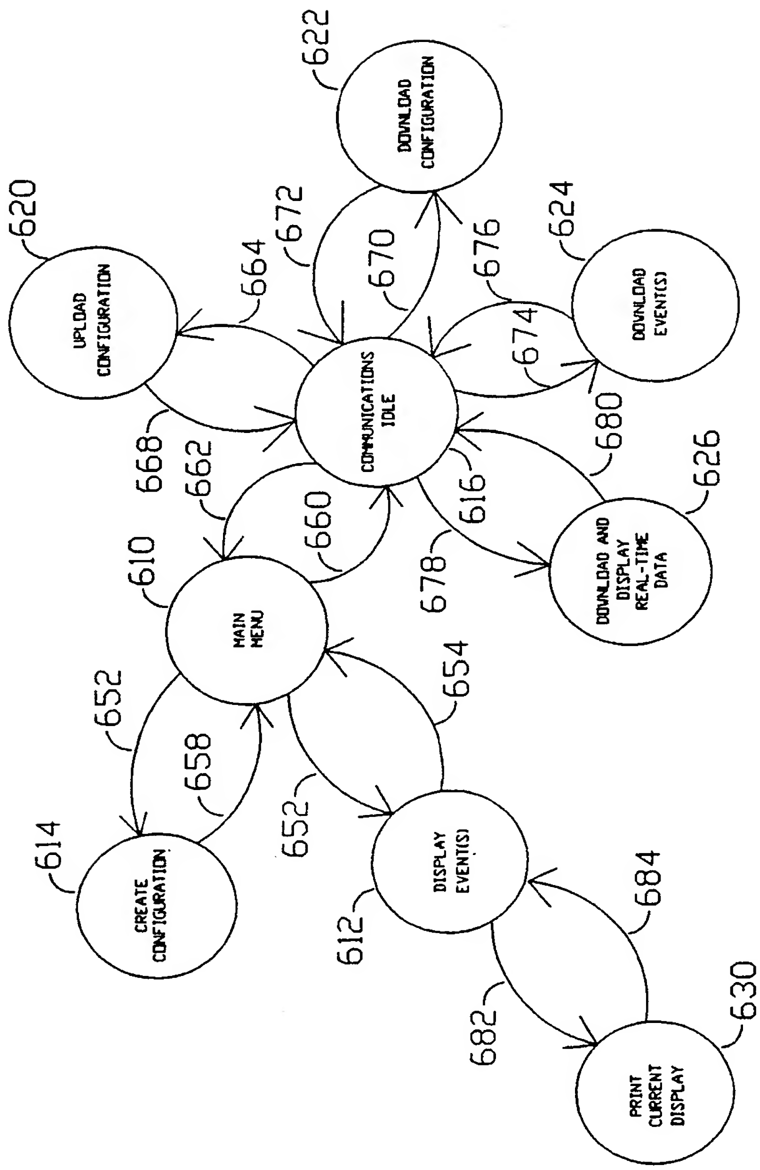

UPLOAD CONFIGURATION
620
DOWNLOAD CONFIGURATION
622
DOWNLOAD EVENT(S)
624
DOWNLOAD AND DISPLAY REAL-TIME DATA
626
COMMUNICATIONS IDLE
616
MAIN MENU
610
CREATE CONFIGURATION
614
DISPLAY EVENT(S)
612
PRINT CURRENT DISPLAY
630
652
654
658
660
662
664
668
670
672
674
676
678
680
682
684

FIG. 9

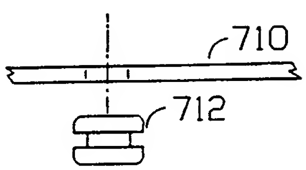


FIG. 10A

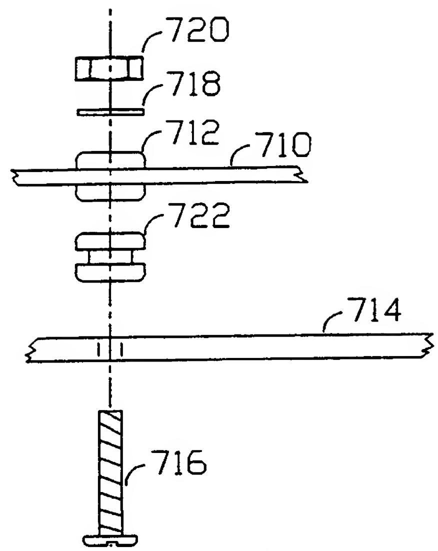


FIG. 10B

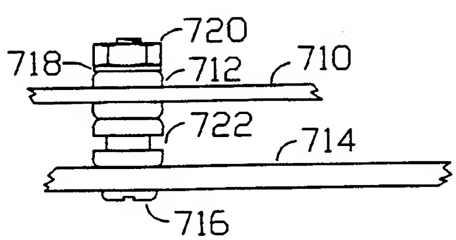


FIG. 10C

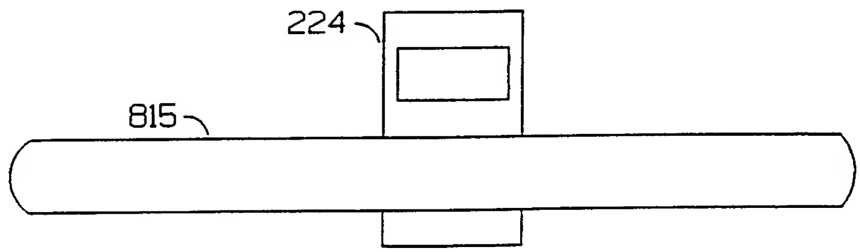


FIG. 11

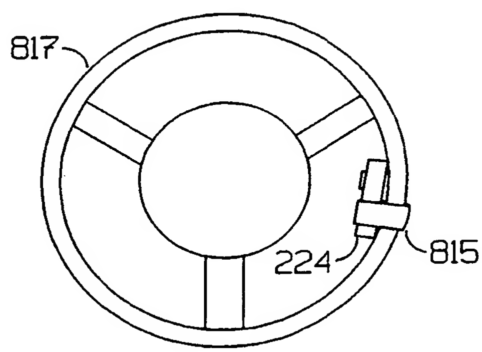


FIG. 12

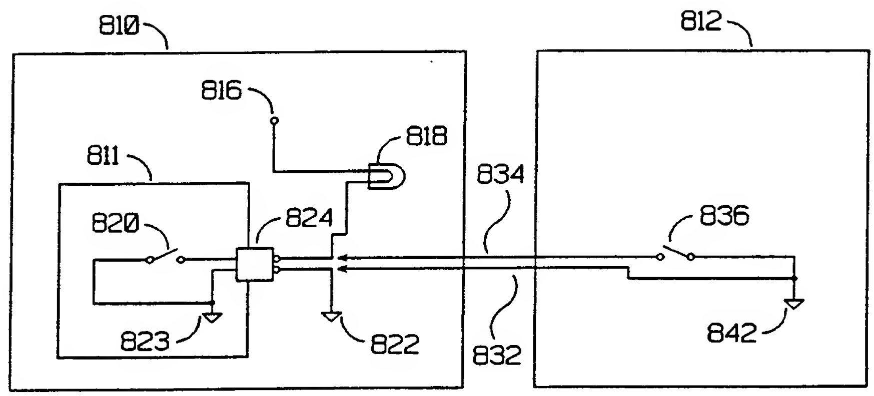

810
812
816
818
811
834
820
824
836
823
822
842
832

FIG. 13

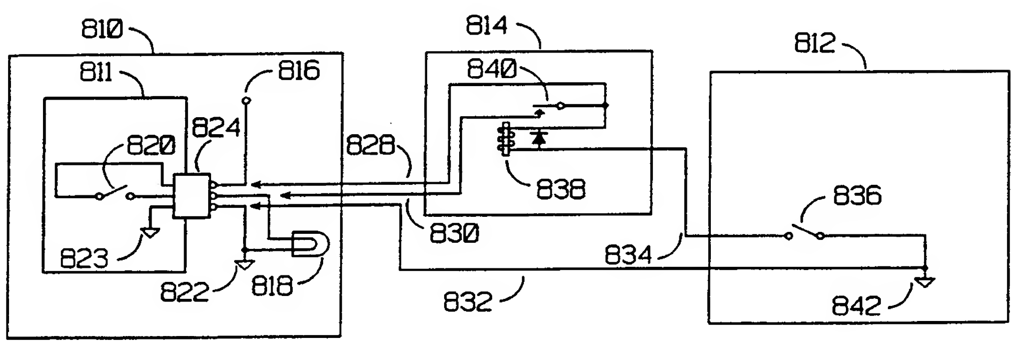

810
814
812
811
840
816
824
820
828
838
836
830
823
834
822
818
832
842

FIG. 14

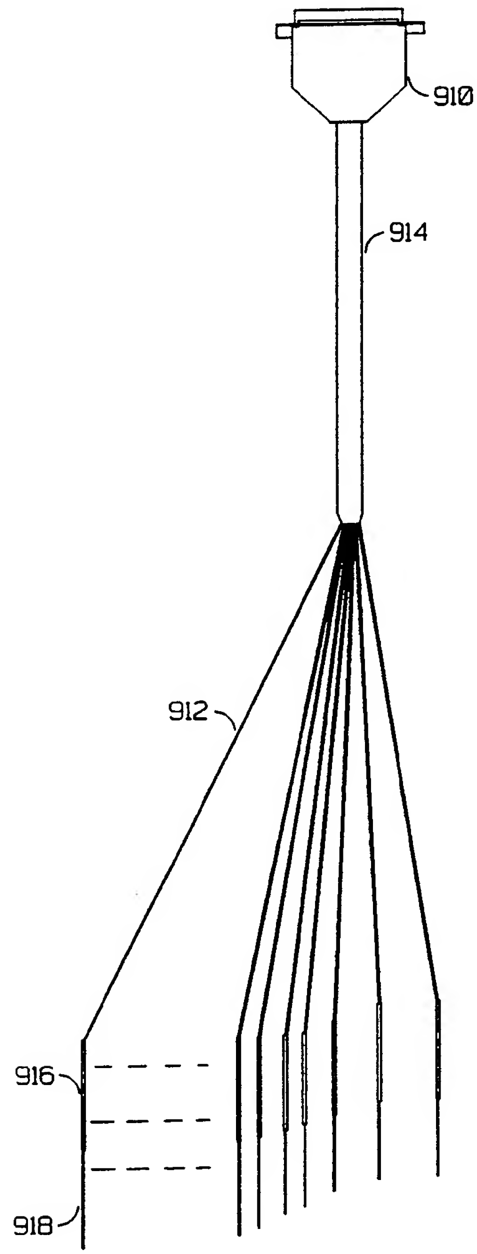


FIG. 15

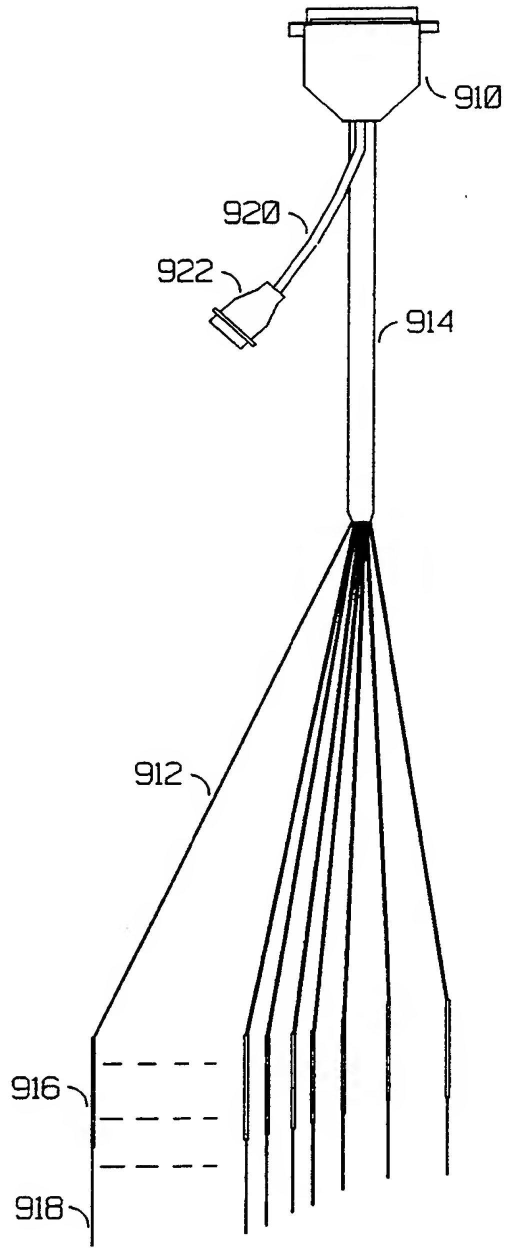


FIG. 16

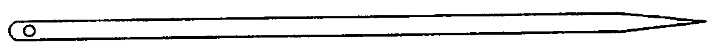


FIG. 17

FIG. 18

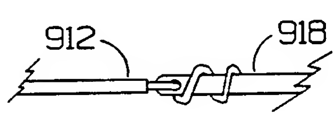


FIG. 19

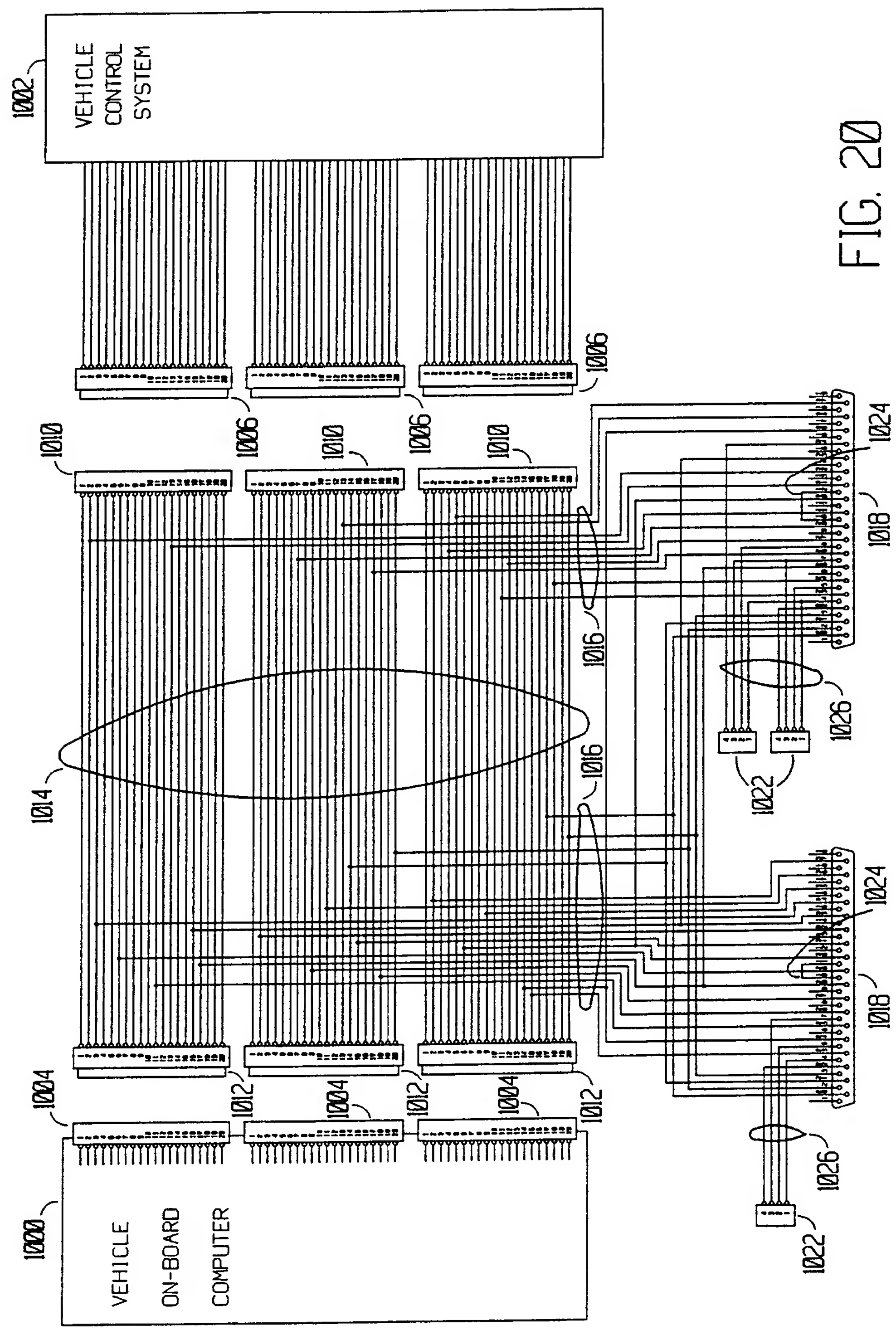

VEHICLE CONTROL SYSTEM
1002
1006
1010
1014
1016
1018
1024
1026
1022
1012
1004
1000
VEHICLE ON-BOARD COMPUTER

FIG. 20

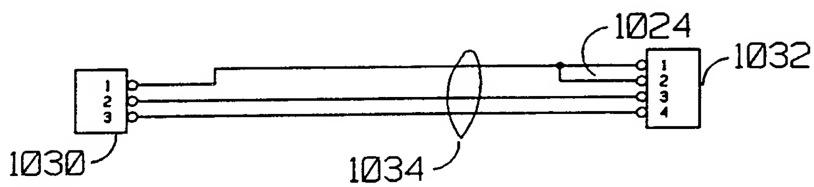


FIG. 21

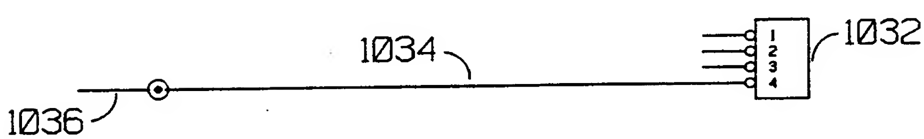


FIG. 22

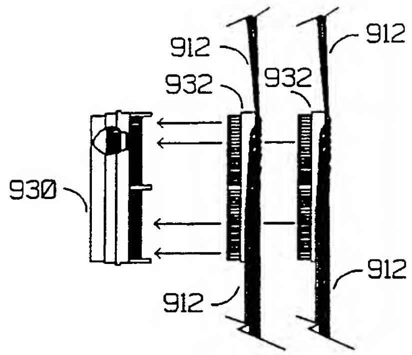


FIG. 23

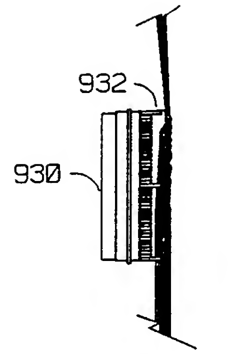


FIG. 24

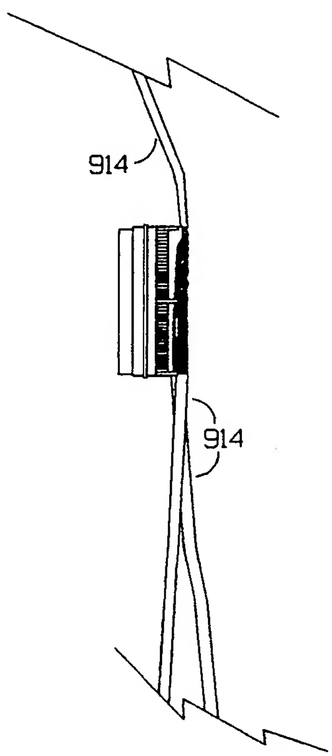


FIG. 25

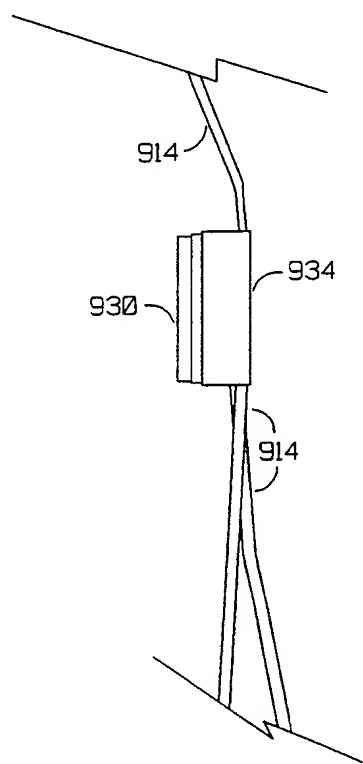


FIG. 26

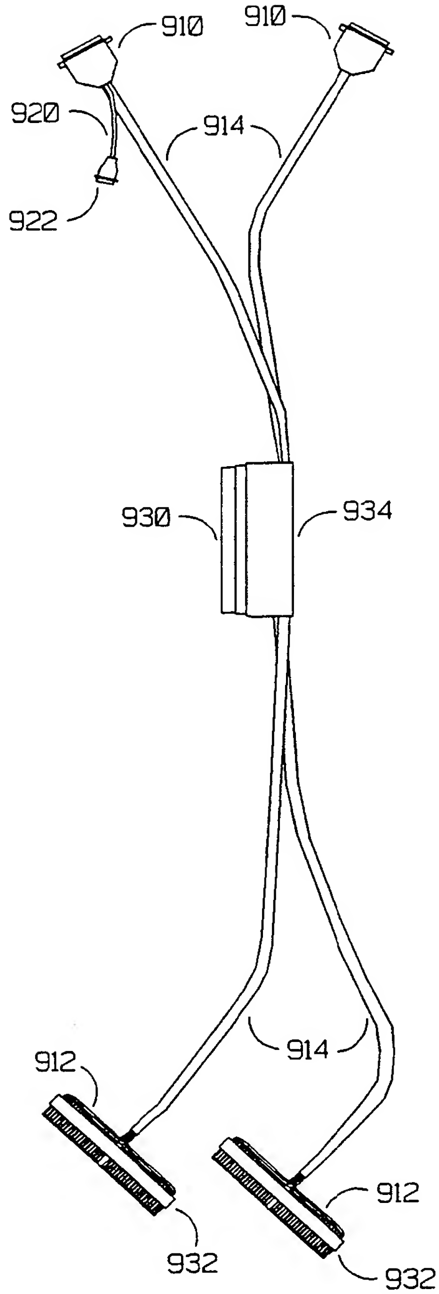


FIG. 27

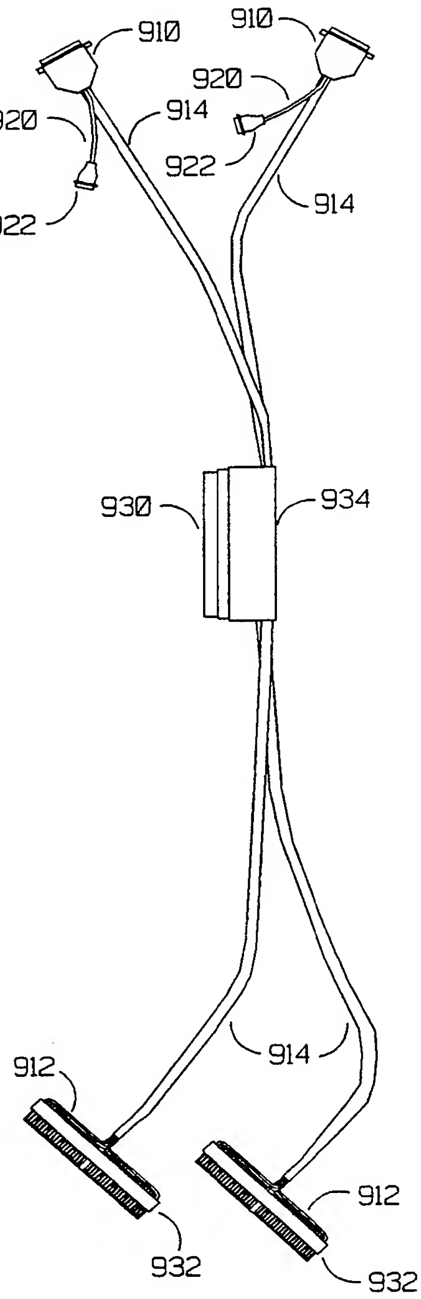


FIG. 28

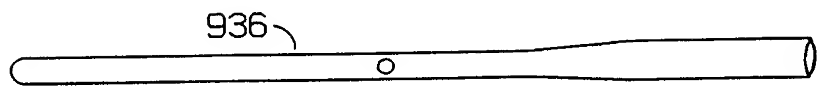


FIG. 29

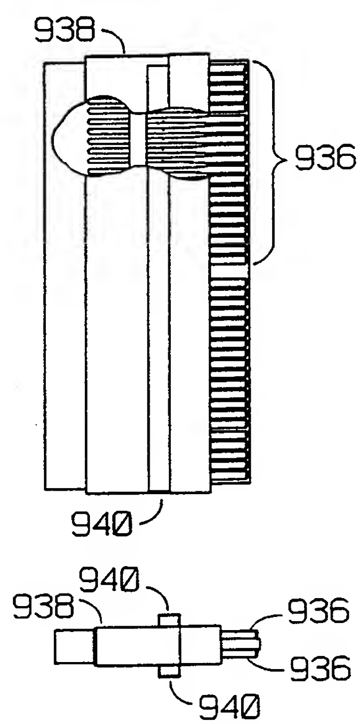


FIG. 30

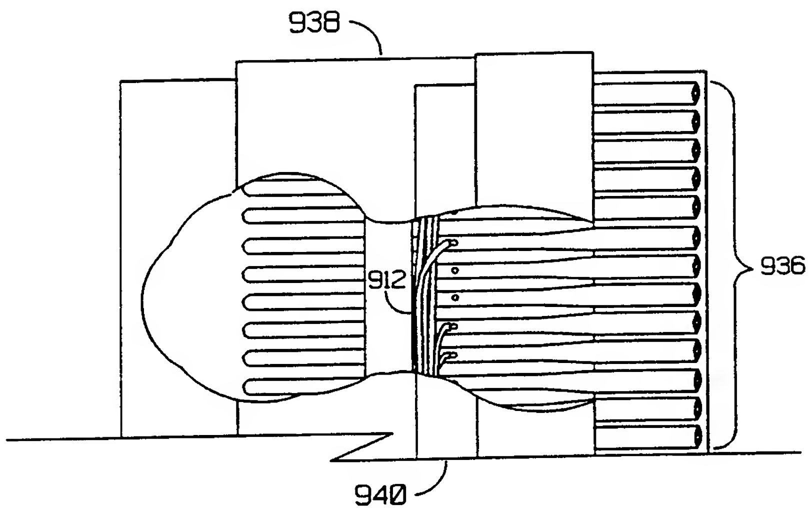


FIG. 31

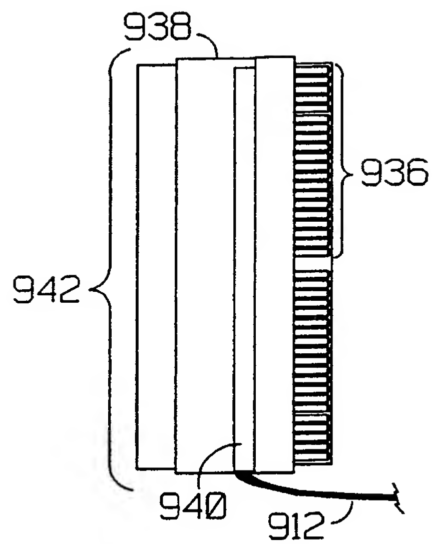


FIG. 32

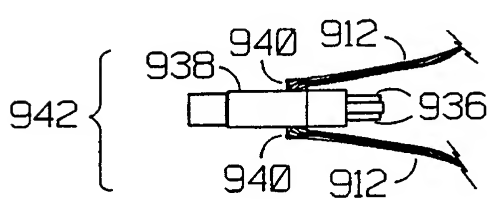


FIG. 33

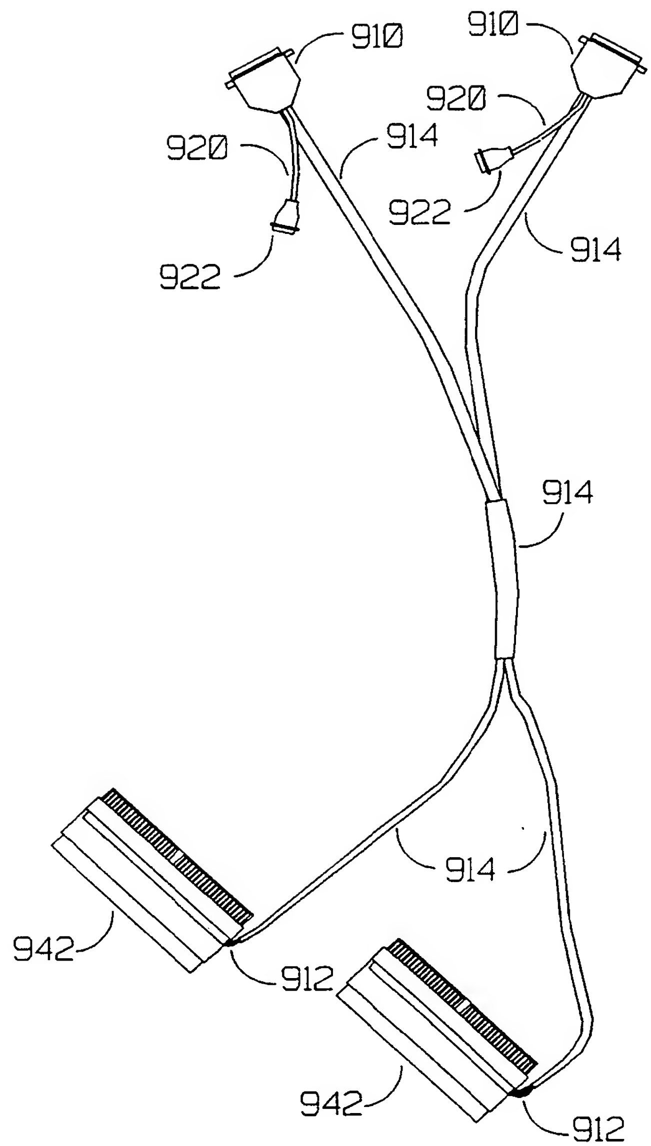


FIG. 34

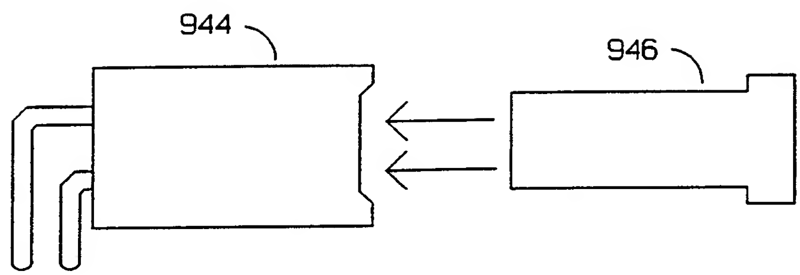


FIG. 35

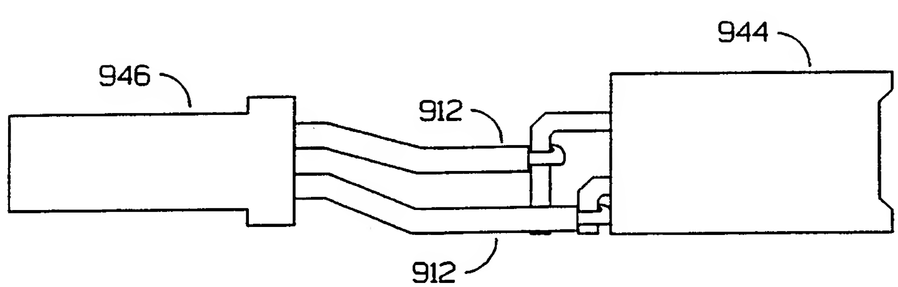


FIG. 36

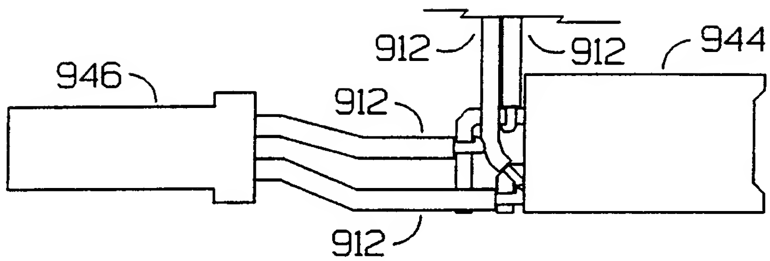


FIG. 37

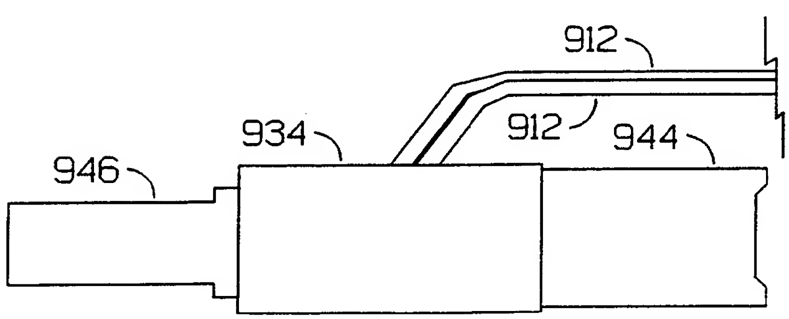


FIG. 38

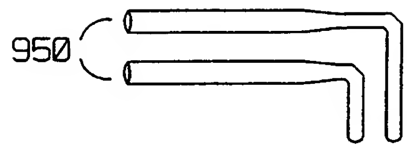


FIG. 39

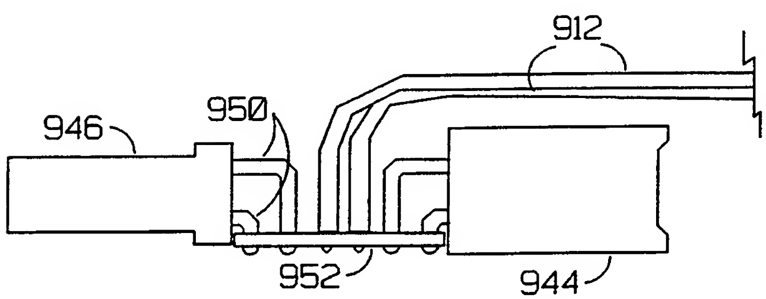


FIG. 40

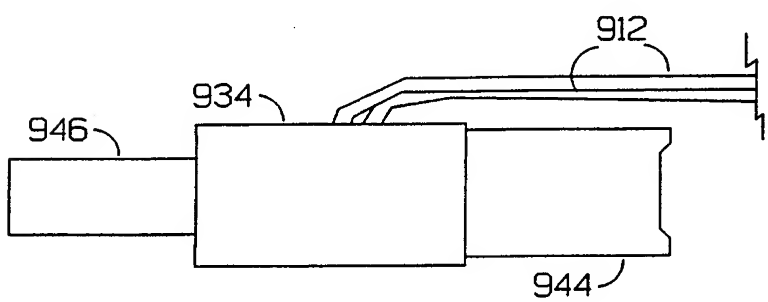


FIG. 41